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Demonstration Erosion Control Project Monitoring Program

Fiscal Year 1995 Report

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Preface

This report discusses work performed during Fiscal Year 1995 by the Hydraulics Laboratory (HL) of the U.S. Army Engineer Waterways Experiment Station (WES) requested and sponsored by the U.S. Army Engineer District (USAED), Vicksburg. The HL merged with the WES Coastal Engineering Research Center in October 1996 to form the Coastal and Hydraulics Laboratory (CHL). WES has now become part of the U.S. Army Engineer Research and Development Center (ERDC).

The report was prepared by personnel of the Waterways and Estuaries Division (WD) , HL, and by the Civil Engineering Department of Colorado State University (CSU), Fort Collins, CO.

WES acknowledges with appreciation the assistance and direction of Messrs. Franklin E. Hudson (retired), Life Cycle Program Manager, USAED, Vicksburg; Larry E. Banks, Chief, Hydraulics Branch, Engineering Division, USAED, Vicksburg; and Charles D. Little, Hydraulics Section, Hydraulics Branch, Engineering Division, USAED, Vicksburg.

The report was prepared under the direct supervision of Messrs. Michael J. Trawle (retired), Chief, Rivers and Streams Branch (RSB), WD; and Thomas J. Pokrefke, Chief, River Engineering Branch, WD; and under the general supervision of Dr. William A. McAnally, Chief, WD; Mr. R. A. Sager (retired), Assistant Director, HL; and Mr. Frank Herrmann (retired), Director, HL. Dr. James R. Houston was the Director of the CHL. This report was prepared by Drs. David S. Biedenharn and Nolan K. Raphelt, RSB, and Chester C. Watson, CSU.

At the time of publication of this report, Dr. Lewis E. Link was Acting Director of ERDC, and COL Robin R. Cababa, EN, was Commander.

1 Introduction

Background

The Demonstration Erosion Control (DEC) project provides for the development of a system for control of sediment, erosion, and flooding in the hill areas of the Yazoo Basin, Mississippi. Features that are being utilized to achieve the project goals include grade control structures, and bank stabilization measures. A variety of grade control structures are being used including a high drop structure similar to the ARS Type-C structure, a low-drop structure similar to the ARS low-drop, and drop box culverts. The bank stabilization measures include the use of longitudinal toe riprap, transverse dikes, bendway weirs and bio-engineered measures such as willow posts. In addition, pipe drop structures are being constructed to prevent gullying on the channel banks due to overland flow into the channel. Other features being employed in the DEC project are levees, pumping plants, land treatments, and developing technologies.

Evaluation of the performance of these features can contribute to the development and improvement of the design guidance. The DEC monitoring project is the first long term monitoring project in the Yazoo Basin. Previous channel assessment studies have yielded only a snap shot in time of the channel conditions. In January 1992, 1993, 1994, and 1995 cross section surveys were conducted at selected sites. Additional sites were added in January of 1993 bringing the total number of sites being monitored to 23. Thalweg surveys of each of the sites were conducted during June of each of the four years. The locations of the watersheds containing the 23 study sites are shown in Figure 1. This report is a summary of the progress made in 1995.

Objective

The objective of the field monitoring program and subsequent data analyses is to continue compiling a database which describes the response of channels to changes in the hydraulic and hydrologic characteristics of the channel. This includes the monitoring of various types of grade control structures and bank stabilization measures to assess the impact on the channel and structural performance. The primary objective of the research is to develop and improve design guidance for the DEC project. The database includes cross section and thalweg surveys and other data for each of the 23 sites.

Several areas of interest to the project are currently being investigated: a) improve the understanding of channel response to bank stabilization measures and

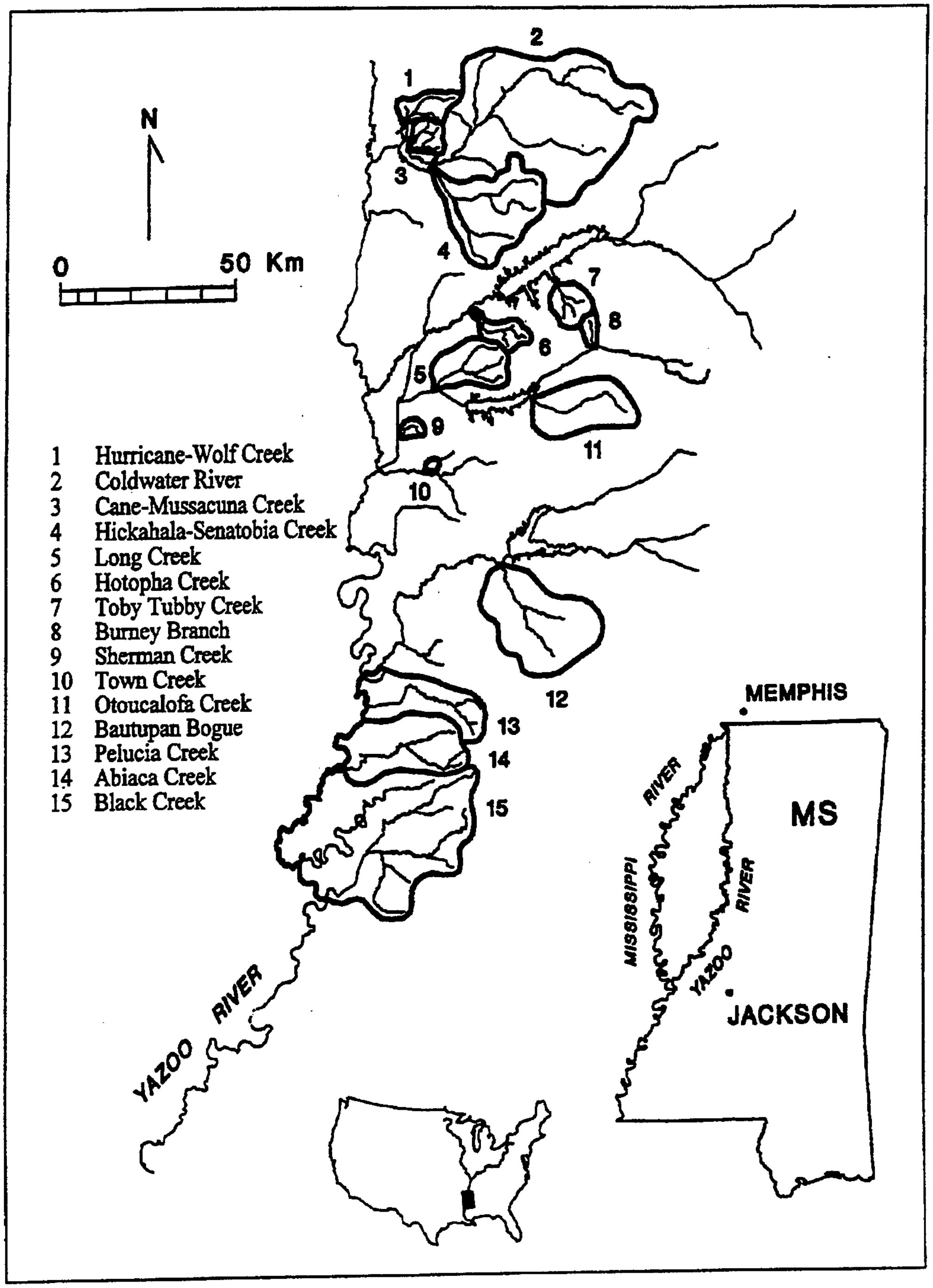


Figure 1. Site location Map (USACE, 1990)

Grade-control structures, b) assess and compare the performance of different bank stabilization techniques, c) define an effective discharge for the channels, d) determine the impacts of lakes, reservoirs and water detention structures on channel response, e) determine the channel roughness and separate bank roughness from bed roughness.

Report Organization

This report is intended to be a reference document for those working on the DEC project. Chapter 2 is a literature review of work that is of particular significance to this report. Comprehensive literature reviews have been presented in previous reports and are not repeated. Chapter 3 describes the location and the results of the analyses of data collected at 25 sites in 1992, 1993, 1994, and 1995. Each section in Chapter 3 is intended to stand alone as an assessment of the state of the channel. Chapter 4 is a summary of the results, and Chapter 5 presents conclusions and recommendations.

2 Literature Review

A review of selected literature is presented in the following sections. A complete review of all pertinent technical and historical data would be voluminous, and only literature directly related to the DEC watersheds or the specific technical procedures is included.

Channel Response Investigations

Earlier evaluations have been of value even though data and the duration of data collection was limited. Watson et al. (1986) evaluated the construction of a series of high-drop structures on Burney Branch, and Harvey and Watson (1988) investigated a series of riprap chutes constructed on Muddy Creek. Burney Branch construction of five structures was designed to remove approximately 60 vertical feet of fall. Major storms in 1978 had resulted in severe erosion that threatened a highway, hospital, and sewerage treatment facility. The primary findings of that evaluation were that the structures were providing significant flood peak attenuation and that the 1984 surveyed slope was 141 percent of the design slope; however, significant improvement in channel stabilization had occurred since construction. The rock chutes in Muddy Creek were installed prior to channelization. The 1988 evaluation showed that the design was very conservative and that, although some adjustment in the cross-section was occurring, Muddy Creek was not actively degrading.

Watson et al. (1988) reported on the evaluation of channel response for several Yazoo Basin low-drop structures. This evaluation was based on comparison of then-current structure surveys with available historic information. Although this data base was limited, several recommendations were reached: design procedures for the low-drop structure must incorporate tailwater definition, upstream aggradation was limited due to the lack of constriction at the weir, little test data existed for operation of the structures at high submergence, and structures should be planned based on a comprehensive watershed stabilization plan. Some of these recommendations have resulted in additional physical modeling to supplement the excellent work by Little and Murphy (1981, 1982).

Watson et al. (1993) reported on the progress of the DEC monitoring investigations at twenty sites for 1992. Conclusions from that report can be summarized in the following paragraphs.

1) Over 300 sediment samples were collected and sieved. Analysis of the samples indicates that fine to medium sand is retained in the bed of the stable streams and is washed away in the bed of the degrading streams. Therefore, if a range of sediment sizes is available to the stream, channel response toward stability should be evident by increasing values in the sorting coefficient (d_{84}/d_{16}).

2) Preliminary comparison of two sediment samplers indicates that a simple pipe scoop is effective in collecting sediment samples for the DEC channels; however, the volume of sample obtained using the pipe scoop may not be sufficient to provide a statistically significant sample.

3) Mixed sand and gravel bed streams exhibit a wide range in average sediment characteristics developed from multiple samples of the same stream. Sand bed streams exhibit little variation in average sediment characteristics developed from multiple samples of the same stream. This implies that different sampling techniques may be required to efficiently characterize the two types of streams. Future computational procedures developed for the design of stable channels may require sensitivity analyses to determine the changes in design parameters that could be caused by bed material variability.

4) The Thorne procedure for slab bank-failure and the Bishop method for rotational bank-failure can be combined to yield a reliable prediction of bank stability for those two modes of failure. However, overbank drainage contributes significantly to channel bank instability in the DEC streams.

5) The range of predicted hydrology developed by others for the DEC streams indicates a limiting source of error in the application of channel design and analysis procedures. Hydrology development was not a task under this contract.

6) Comparisons of the width, depth, and hydraulic slope of the monitoring site cross-sections with the regime hydraulic geometry relationships were made. Based on the 1992 monitoring data, seven stable channel sites indicated that the width is less than or equal to the regime predicted width, depth is generally greater than the regime predicted depth, and the slope is generally greater than predicted by the regime predicted slope. However, the regime hydraulic geometry relationships serve as a useful benchmark by which channel may be compared.

7) The lack of sensitivity of the bed-slope versus drainage area curve to watershed hydrology modification is a principal reason for the need to improve design techniques.

Raphelt, et al. (1993) summarized the findings resulting from survey comparisons and backwater computations for the Hickahala-Senatobia watershed, the Long Creek watershed, and the Batupan Bogue watershed. Comparison of the Hickahala-Senatobia hydraulic data with regime curves (EC 1110-8-1FR, HQUSACE, 1990) indicated that with few exceptions the channel is narrower than predicted by regime, the observed depth was similar to the predicted depths, and the observed channel slope was steeper than regime predictions. In Long Creek watershed, the data was inconsistent and ranged widely in the comparative graphs of width, depth, and slope. Channel slopes were all steeper than expected. The results of the Batupan Bogue analyses indicated similar trends as found in Hickahala-Senatobia watershed. Data was analyzed only for the downstream, relatively stable, portions of tributaries due to data limitations. Appendices A, B, and C (Waller and Hubbard, 1993) of the main report (Raphelt et al., 1993) provides valuable cross-section and thalweg comparison plots.

Watson et al. (1994) summarized the DEC monitoring program conducted by CSU and the conclusions drawn from that are summarized in the following paragraphs.

1) Comparison of the 1992 and 1993 average sediment discharge concentration indicates that the 2-year sediment discharge has been reduced by approximately 15%.

2) Two primary design goals have been the focus of the DEC project: arrest headcut migration and induce channel stability for the prevailing sediment supply; and control sediment yield and induce channel stability for the desired sediment supply. Design for a new, desired sediment yield goal introduces an added dimension to the geomorphic model of channel evolution, which indicates that the slope-area relationship must be modified to specifically include sediment yield.

3) Prior empirical stability criteria have not included sediment discharge or sediment yield directly, and have been based on the observation of channel morphology, vegetation and change in thalweg elevation or the water surface elevation of a specific discharge. While geomorphic stability can be implied by these observations as a balance between sediment supply and sediment yield, design to accommodate a specific sediment yield goal cannot be accomplished using empirical, geomorphic-based methods. Quantification of sediment yield and the relationship between channel morphology and sediment discharge must be included in the design of channel stabilization measures for the control of sediment transport to downstream reaches.

4) The sediment supply reach concept is common to most sediment transport models, and is necessary to produce reasonable results. Sediment supply, size, and distribution are required at the upstream model boundary as input to the model. In drastically disturbed channels, the rate of sediment supply may be too great to be acceptable as a design input, and the size of the sediment being sampled in the proposed supply reach may not be representative of sediment that will comprise the future stable channel.

5) Develop sufficient hydrology to define reliable flow-duration relationships for any site in the DEC.

6) Develop design procedures for stabilization measures incorporating a selected project sediment yield goal.

7) Concentrate efforts to assess channel hydraulic roughness data.

8) SAM and HEC-6 should include the capability to model gravel and mixed-bed sediments.

Drop Structure Testing and Evaluations

A series of hydraulic model tests have been conducted at Colorado State University by Abt et al. (1991) to evaluate the low-drop structure under conditions of flow that were not considered by Little and Murphy (1981, 1982). Additional physical model testing was conducted by WES (Raphelt, et al., 1993). Results from the Colorado State University tests indicated that riprap stability in many of the existing structures was poor, and field confirmation of the riprap instability has been documented by Lenzotti and Fullerton (1990).

The objective of an evaluation of DEC drop structures (Watson and Abt, 1993, Watson, Abt and Little, 1995) was to document the condition of U.S. Army Corps of Engineers high-drop and low-drop grade control structures constructed in the Yazoo Basin as part of the Demonstration Erosion Control (DEC) program, to recommend restoration measures for these structures if necessary, and to establish a priority for maintenance if required. A general objective of this research was to contribute to the development of improvements in the general design of grade control structures, and to compare the various types and ages of structures to develop a database that may be useful in predicting restoration needs and design improvements for similar structures.

Although each structure operates under unique conditions, many similarities exist and some of the problems that were observed can be summarized. Common low-drop structure problems are as follow:

a. Riprap is displaced from the face of the weir.

b. The channel bank upstream or downstream of the structure fails.

c. Bank erosion or piping beneath the riprap that is caused by overbank drainage.

d. Riprap is launching at the upstream or downstream apron.

e. Severe headcutting is migrating into the basin.

f. Woody vegetation has become established in the upstream or downstream apron, and is impairing the conveyance or the weir unit discharge of the structure.

g. Active incision is present downstream of the structure.

h. The thalweg upstream of the structure is below the weir crest for more than 500 feet.

The comparison of 1993 and 1995 frequency of problems expressed as percentages are given in the following tabulation.

	Problem	1	2	3	4	5	6	7	8
1993		41%	37%	24%	28%	17%	19%	-	-
1995		37%	23%	18%	43%	37%	11%	69%	78%

Gessler et al., (1995) report the results of a model study of drop structures. The objective of the model study was to develop rating curves for four drop structures. Models of each drop structure were constructed at a 1 to 30 scale and tested in a laboratory flume. A total of 104 flume experiments were conducted. The data collected was used to develop rating equations for each of the four structures tested, each of which has an r-squared value greater than 0.99.

A comparison of the different structures was made to determine the impacts of changing certain aspects of the structure geometry. It was demonstrated that a low flow notch through the structure is an effective means to lower the upstream water surface elevation at low flow without changing the rating curve significantly at the higher flows. It was also shown that a three dimensional trapezoidal structure with the sloping walls bent forward has slightly greater head loss than the same structure constructed in one plane. The results of the investigation indicate that structures with the same basic geometry as the models tested can be modified to create a variety of desired rating curves.

Bank Stabilization Evaluations

Zevenbergen and Watson (1990) prepared a report for the Vicksburg District documenting several types of bank stabilization measures that have been constructed in Yazoo Basin streams since approximately 1973. These methods included permeable and impermeable dikes, longitudinal riprap dikes, wooden fences, devices constructed of used automobile tires, hay, and other methods. The study provided a ranking of the likelihood of success as a function of cost, and as a function of the erosive radial force at a particular location. Two primary factors that related to the precision of that study were the lack of regular repeat surveys and the lack of stream-flow information.

Watson et al., (1995) present the results of research to analyze the performance of bank stabilization techniques applied to arrest bend migration, to assess placement of riprap bank stabilization, and to monitor bank stabilization methods for the purpose of developing design guidance. The methodology for this research combined field data acquisition, literature review, and review of the Vicksburg District channel stabilization plans and specifications. Field data were collected at the following Yazoo Basin sites: Little Bogue, Harland Creek, Red Banks Creek, Goodwin Creek, and Otoucalofa Creek. The following general conclusions have been reached in this investigation:

1) Riprap streambank stabilization measures are constructed of adequately sized stone;

2) Techniques for placement and construction of riprap bank stabilization in far beyond the traditional full bank revetment;

3) More emphasis should be placed on the development, testing, and monitoring of experimental stabilization measures, such as bioengineering, to develop reliable engineering design criteria; and

4) Greater importance should be attached to hydraulic, geomorphic, and geotechnical analyses in the design of bank stabilization.

Watson et al. (1995) present designs for experimental bioengineered bank stabilization of five sites along Harland Creek, a tributary to Black Creek in the Yazoo Basin of Mississippi. Each site was selected to address different types of bank stabilization problems. A combination of six different bioengineering techniques will be used to stabilize these sites. Harland creek is monitored as part of the DEC project, with stream gauging and with comparative field surveys. Although many sites have been stabilized using bioengineering, these sites will have comprehensive monitoring and a review of conditions before and after construction.

Bank Stability Investigations

Degradation of the bed of a stream results in the increase of the channel bank height. If the bank exceeds the critical bank height threshold, mass failure of the banks can occur (Thorne et al., 1981, Watson et al., 1988). The critical bank height is dependent on the geotechnical properties of the bank materials. Fluvial erosion of the banks does not appear to be as significant as mass failure, but continued bank failure depends on fluvial removal of the failed materials at the toe of the slope (Thorne, 1982, Harvey and Watson 1986). The type of bank failure that occurs after the critical bank height has been exceeded depends on both the type of materials and time. Initially, slab failures occur (Thorne et al., 1988), but eventually the failure mode changes to circular arc. Because of the great height of the banks, it is doubtful if top bank vegetation has any positive effect on bank stability. This is in contrast to the situation in small streams where top-bank vegetation significantly affects bank stability. However, vegetation developing at the toe of the channel bank may increase the effective shear resistance of basal deposits and thus, have a significant effect on bank stability.

Mass failure of the incised channel banks causes channel widening and an increase in the supply of sediment to the channel. The bed and banks of an incised channel become a reservoir to supply sediment to the channel. Up to 75 percent of the total watershed sediment yield can be due to channel erosion (Watson et al., 1986). Channel widening will continue until the failed materials are no longer removed by fluvial processes. This channel widening is accompanied by both bank reduction due to aggradation and bank angle reduction due to accumulation of the failed bank materials at the toe of the slope. Once the materials are no longer transported, vegetation colonizes the base of the bank, and stability of the site is enhanced (Simon and Hupp, 1987).

Biedenharn et al. (1990) documented stabilization of the banks of Long Creek that occurred upstream of a low-drop structure. Construction of the structure enhanced bank stability by reducing bank height and by limiting the transport capacity of the stream. This case study clearly demonstrated the value of drop structures as bank stabilization features; however, the monitoring, which occurred in January, 1992 documented severe erosion at these sites. This emphasizes the importance of long-term monitoring over a period of several years, and that long-term monitoring is essential to judging the effectiveness of a stabilization feature.

March et al. (1993) prepared a report to document a computer program, BANKSTAB, which can be utilized to compare surveyed channel banks with a regional bank stability curve. The program allows rapid estimation of bank stability using regional soil parameters and HEC-2 input files for defining bank geometry. BANKSTAB does not account for concurrent change in bank height and bank angle, and modification of the program to incorporate this feature is underway.

In the incised channels of the Yazoo Basin, a fixed lateral boundary for the channel is a simplification because considerable channel widening takes place as a result of degradation. Bank failure provides considerable sediment inflow to the channel. This adjustment should be considered in developing future models for analysis, and modification of previous bank stability models has been made in FY-1994 to develop the BURBANK computer program. BURBANK is a basic language computer program that quickly assesses the bank stability for a channel reach. The program uses a HEC-2 data input file to describe channel morpholoby, and the user inputs the friction angle, specific weight, and cohesion of the bank materials. An important assumption is that the bank materials is homogenous. Output from the program is the percentage of the bank at risk of failure for existing or for user-supplied amounts of degradation. The program can also create a new HEC-2 file that approximates the post-failure and clean out condition.

Raphelt et al., (1995) present a method for determining the required channel stabilization methods using two computer programs. SAM (USACE, 1993) is used to determine the stable slope for the channel. If the actual slope exceeds the stable slope, a grade control structure will be necessary. Raphelt then uses the program BURBANK developed at Colorado State University to determine the percentage of bank line at risk of failure. BURBANK utilizes the HEC-2 input deck to determine the geometry of the banks of the channel. The factor of safety against slab failure and rotational failure is computed. If the factor of safety is less than one, the bank is considered to be at risk of failure and measures should be taken to increase bank stability. Such measures include reducing the bank height or bank angle or increasing the soil stability. The soil stability can be increased by planting willow posts of through bio-engineering methods.

Stream Classification

Although applicable only to incised channels, the conceptual incised channel evolution model (CEM) has been of value in developing an understanding of DEC watershed and channel dynamics, and in characterizing stable reaches of these channels. The sequence was originally used to describe the erosion evolution of Oaklimiter Creek, a tributary of Tippah River in northern Mississippi.

Location-for-time substitution was used to generate a five-reach type, incised channel evolution sequence for stream of the Yazoo Basin (Schumm et al., 1981, 1984), as shown in Figure 2. In each reach of an idealized channel, Types I and V occur in series and, at a given location, will occur in the channel through time. The channel evolution model describes the systematic response of a channel to base level lowering, and encompasses conditions that range from disequilibrium to a new state of dynamic equilibrium. The following paragraphs characterize the conceptual types. It should be recognized that these categories are only conceptual and variation may be encountered in the field.

Type I reaches are characterized by: a sediment transport capacity that exceeds sediment supply, bank height (h) that is less than the critical bank height (hc), a U-shaped cross section, small precursor knickpoints in the bed of the channel providing that the bed material is sufficiently cohesive (Biedenharn, 1989), and little or no bed material deposited. Width-depth ratios at bankfull stage are highly variable.

Type II reaches are located immediately downstream of the primary knickpoint and are characterized by: a sediment transport capacity that exceeds sediment supply, a bank height that is greater than the critical bank height (h>hc), little or no bed sediment deposits, a lower bed slope than the Type I reach, and a lower width-depth ratio value than the Type I reach because the depth has increased but the banks are not failing.

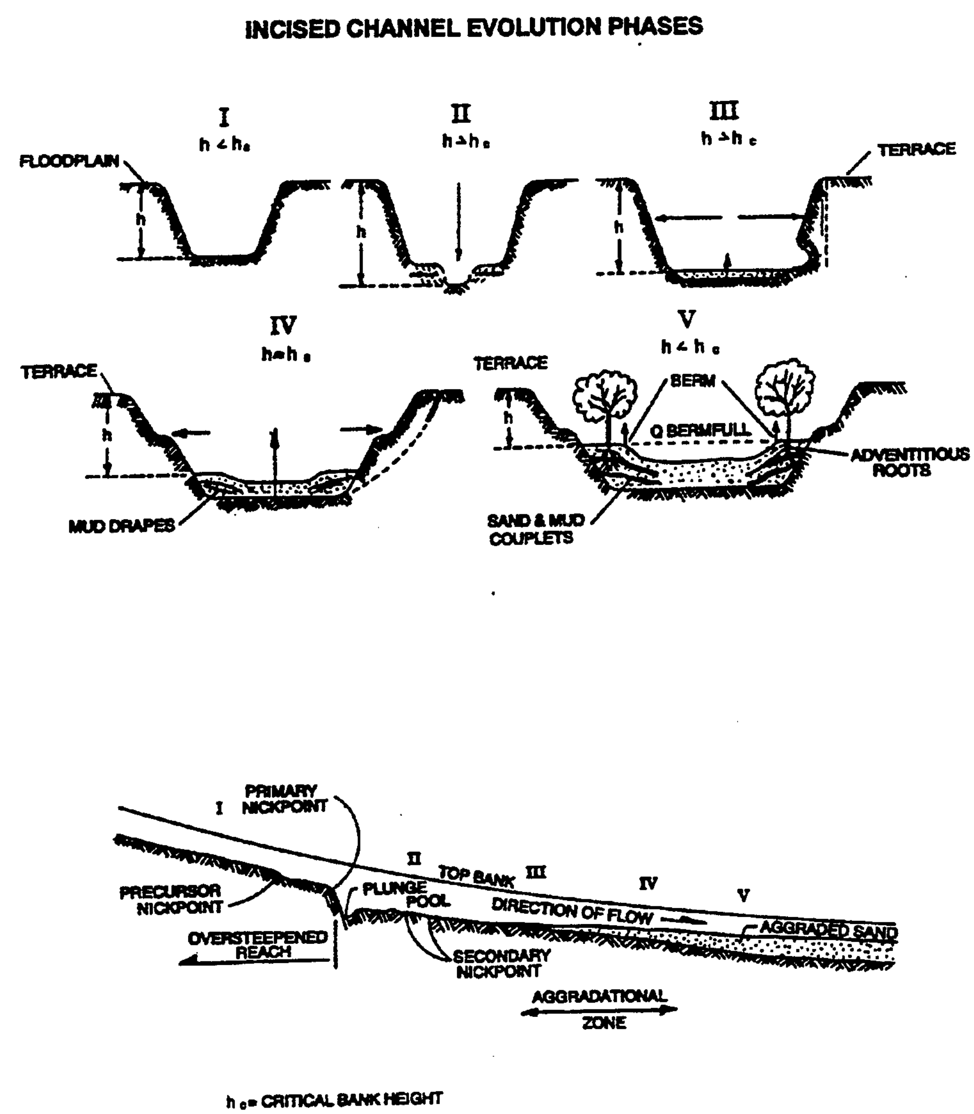


Figure 2. Incised Channel Evolution Sequence (after Schumm et al., 1984)

Type III reaches are located downstream of Type II reaches and are characterized by: a sediment transport capacity that is highly variable with respect to the sediment supply, a bank height that is greater than the critical bank height (h>hc), erosion that is due primarily to slab failure (Bradford and Piest, 1980), bank loss rates that are at a maximum, bed sediment accumulation that is generally less than two feet, but can locally be greater due to local erosion sources, channel depth that is somewhat less than in Type II. The channel is widening due to bank failure.

Type IV reaches are downstream of Type III reaches and are characterized by: a sediment supply that exceeds sediment transport capacity resulting in aggradation of the channel bed, a bank height that approaches the critical bank height with a rate of bank failure lower than Type III reaches, a nearly trapezoidal cross-section shape, and a width-depth ratio higher than the Type II reaches. The Type IV reach is aggradational and has a reduced bank height. Bank failure has increased channel width, and in some reaches the beginnings of berms along the margins of an effective discharge channel can be observed. These berms are the initiation of natural levee deposits that form in aggraded reaches that were over-widened during earlier degradational phases. Bradford and Piest (1980) observed that in the later phases of evolution, the mode of bank failure changes from circular arc to slab-type failures.

Type V reaches are located downstream of Type IV reaches and are characterized by: a dynamic balance between sediment transport capacity and sediment supply for the effective discharge channel, a bank height that is less than the critical bank height for the existing bank angle, colonization by riparian vegetation, an accumulated bed sediment depth that generally exceeds 3 feet, a width-depth ratio that exceeds the Type IV reach, and generally a compound channel formed within a newly formed floodplain. The channel is in dynamic equilibrium. Bank angles have been reduced by accumulation of failed bank materials at the toe of the slope and by accumulation of berm materials.

The sequence of channel evolution is based on the assumption that the observed changes in channel morphology are due to the passage of time in response to a single base level lowering without changes in the upstream land use and sediment supply from the watershed. Application of the sequence assumes that the materials forming the channel perimeter are erodible and all degrees of the channel adjustment are possible. The sequence is applicable only in a system context, and local erosion such as in bends or caused by deflection of flow by debris may cause difficulty in application of the sequence.

The primary value of the sequence is to determine the evolutionary state of the channel from a field reconnaissance. The morphometric characteristics of the channel reach types can also be correlated with hydraulic, geotechnical, and sediment transport parameters (Harvey and Watson, 1986; Watson et al., 1988). An understanding that reaches of a stream may differ in appearance, but channel form is associated with other reaches by an evolving process. Form, process, and time relate dissimilar reaches of the stream.

The USAED Vicksburg (1990) used the channel evolution sequence in developing regional stability curves relating the bed slope of Type V reaches as a function of the measured drainage area. Quasi-equilibrium, Type V reaches were determined by field reconnaissance of knowledgeable personnel. Figure 3 is an example of the empirical bed slope and drainage area relationship for Hickahala Creek, in northern Mississippi. The 95% confidence intervals of the regression line

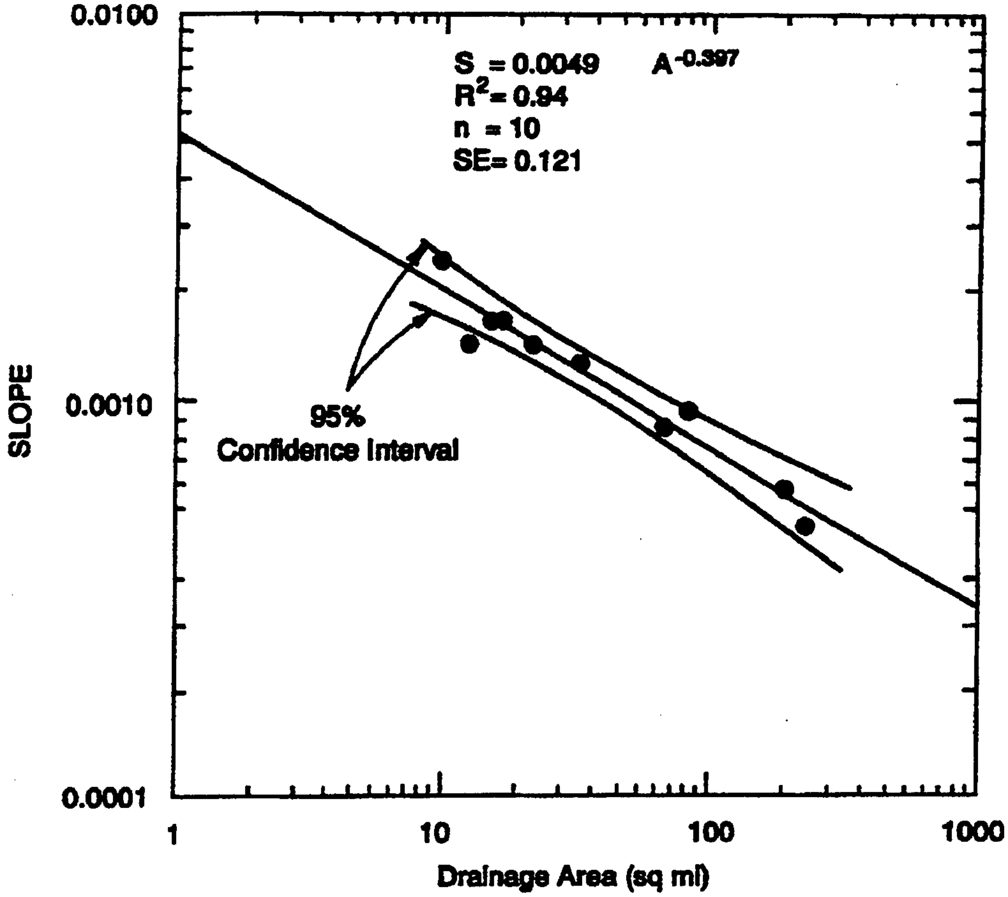


Figure 3. Hickahala Creek watershed, slope-drainage area relationship

are shown. The slope-area curve is an example of many empirical relationships that do not explicitly include the primary factors of water and sediment discharge, sediment load, hydraulic roughness, and channel morphology, but require implicitly that these factors are considered.

Watson et al., (1995) state that stream classification is an essential element in transferring knowledge and experience pertaining to channel design from location to location. A computer program was developed to record a comprehensive data set for a watershed and for channel sites, and to present alternative classification of each based on three classification systems: Schumm (1977), Rosgen (1994), or Montgomery and Buffington (1993). A goal of the program is to develop understanding between groups who are most familiar with only on or two of the classification systems compared.

Quantification of the Evolutionary Sequence

The parameters of the Oaklimiter Sequence are difficult to quantify and to incorporate in design guidance. The parameters can be compressed into two dimensionless stability numbers, Ng and Nh. Ng is a measure of bank stability and Nh is a measure of sediment continuity. For a channel to be stable, sediment continuity and bank stability are essential.

Ng is defined as the ratio between the existing bank height and angle (h) and the critical bank height at the same bank angle (hc). Bank stability is attained when Ng is less than unity ($Ng < 1$). Therefore, Ng provides a rational basis for evaluating the requirements for bank stabilization and for evaluating the consequences of further bed degradation.

The hydraulic stability number, Nh, is defined as the ratio between the desired sediment supply and the actual sediment transport capacity. Sediment continuity yields $Nh = 1.0$. It is important to note that the definition of Nh includes sediment transport and supply, which is in contrast to most channel design procedures that are fixed boundary approaches. Nh provides a rational basis for evaluating the equilibrium sediment-transport sediment-supply relationship that is required to achieve a state of dynamic equilibrium. Hydraulic stability in the channel is attained when $Nh = 1$. If Nh is < 1 the channel will degrade, and if Nh is > 1 it will aggrade. Since sediment supply to a channel can change through time, it is prudent to design rehabilitation measures that will allow for the fluctuations in sediment supply.

In combination, Ng and Nh provide a set of design criteria that define both bank and hydraulic stability in the channel. Grade-control structures constructed in the channel should induce upstream deposition of sediment in the bed of the channel. This emulates the natural evolution of the channel. Reduction in the sediment transport capacity as a result of slope reduction permits deposition of sediment. This reduces the bank height of the channel. Continued bank erosion will occur only if the failed bank materials are removed by fluvial processes. The aggradation upstream of the grade-control structure eventually will result in increasing bank stability.

The dimensionless stability number, Ng and Nh can be related to the channel evolution modes, as shown in Figure 4. As the channel evolves from a state of disequilibrium to a state of dynamic equilibrium through the five reach types of the Oaklimiter Sequence, the channel condition will progress through the four stability diagram quadrants in a counter-clockwise direction. Rehabilitation of the channel should attempt to omit as many of the quadrants as possible to reduce the amount of channel deepening and widening.

Each quadrant of the stability diagram is characterized by geotechnical and hydraulic stability number pairs, and stream reaches that plot in each quadrant have common characteristics with respect to stability, flood control, and measures that may be implemented to achieve a project goal.

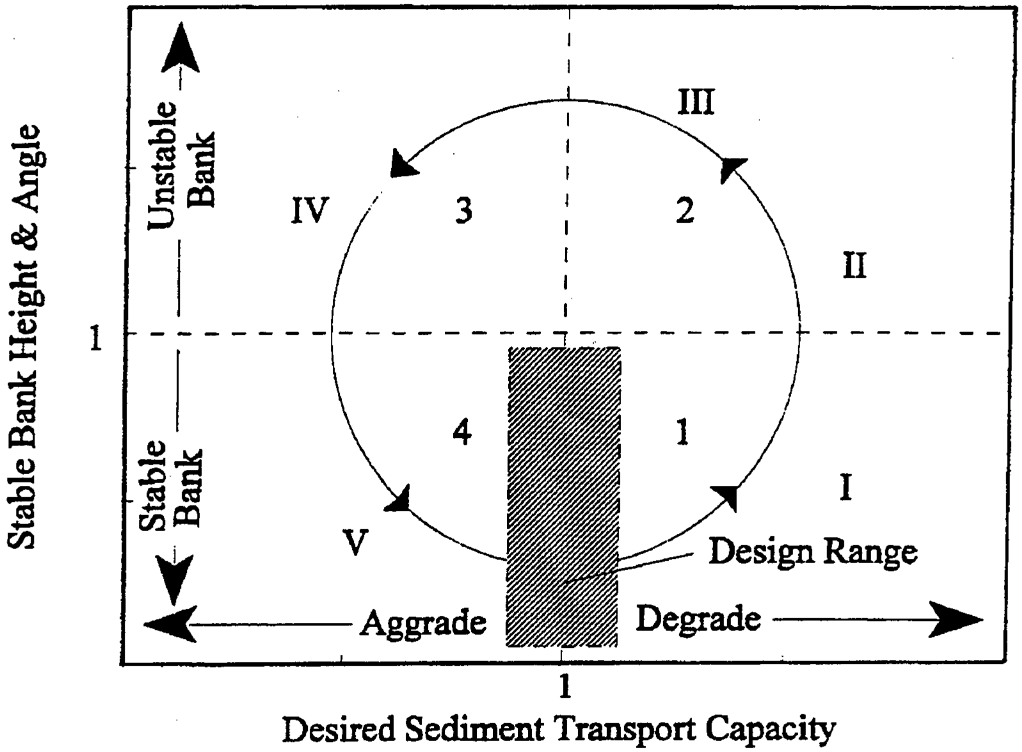


Figure 4. Comparison of channel evolution sequence and channel stability diagram

Quadrant 2 (Ng>1, Nh>1) streams have a very severe stability problem; the channel bed is degrading and channel banks are geotechnically unstable. Grade control must be used to reduce bed slope, transport capacity, and Nh. Both flood control and bank stability must be considered when determining the height to which grade control should be constructed. A series of grade control structures can reduce bank height enough to stabilize the banks, but a combination of grade control and bank sloping may better resolve flood control while meeting stability objectives. Quadrant 1 (Ng<1, Nh>1) is not a severe stability problem; the channel bed may be degrading or may be incipiently degradational, but the channel bank is not geotechnically unstable. Bank erosion is occurring only locally and bank stabilization measures such as riprap, dikes, or vegetation could be applied. However, local stabilization would not be successful if bed degradation continued and destabilized the channel stabilization measures. If flood control is a project goal, almost any channelization measure or construction of levees would increase the Nh instability, shifting the value to the right and increasing the opportunity to make Ng>1. Flow control using a reservoir can address flood control and improve stability if the new flow duration curve reduces comulative sediment transport; however, changing the flow duration curve and reducing the available sediment supply are potentially destabilzing. Each of these factors should be considered in projects involving Quadrant 1 channels. Bed stabilization through the use of a grade control structure or bed stabilization element may be desirable.

Quadrant 3 (Ng>1, Nh<1) has a sever and dynamic problem with gravity driven bank failure, but without continued bed degradation. Bank sloping could be effective without grade control emplacement, but usually both measures should be considered. Local bank stabilization measures in either Quadrant 2 or 3 are unlikely to be successful. Flow control in these two quadrants could be beneficial, but must be considered in the context of extreme reach instability, and grade control is likely to be required.

Quadrant 4 (Ng<1, Nh<1) is characterized by general stability. Local bank stabilization measures will be effective. As Nh decreases in this quadrant, the potential for channel aggradation-related flood control problems increases.

The desirable range for long-term channel stability is for Ng to be less than one, and for Nh to be approximately one (Ng<1, Nh=1). If flood capacity is not sufficient as Ng increases to 1.0, levees or a compound channel should be considered.

The USAED Vicksburg (1990) used the channel stability diagram in discussions of Nelson, Beards, Catheys, and James Wolf Creeks stability, as shown in Figure 5. Figure 6 depicts the change in plotting positions of the result of channel stabilization measures that move two streams from degradation to aggradational (Stream A), and from degradational to unstable banks to aggradational and stable banks (Stream B). The proper characteristics for long term stability are neither aggrading nor degrading, with stable banks.

Hydraulic and Sediment Transport Analyses

Two computer programs, HEC-2 and SAM, have primarily been used for hydraulic and sediment transport analyses. HEC-2 (USACE, 1982) has been used in the analysis and in design of measures for DEC streams, and has served as a basis for sediment transport analysis. Hydraulic analyses are being conducted using the U.S. Army Corps of Engineers HEC-2 water surface profile model. The HEC-2 output is used to: 1) define the hydraulic conditions and bankfull discharge; 2) define hydraulic parameters for sediment transport and related analyses; and 3) define water surface elevations for flows of given recurrence intervals. The channel cross-sections used in the hydraulic investigation are those from the field survey. Proper use and calibration of the HEC-2 model is enhanced by the field observations.

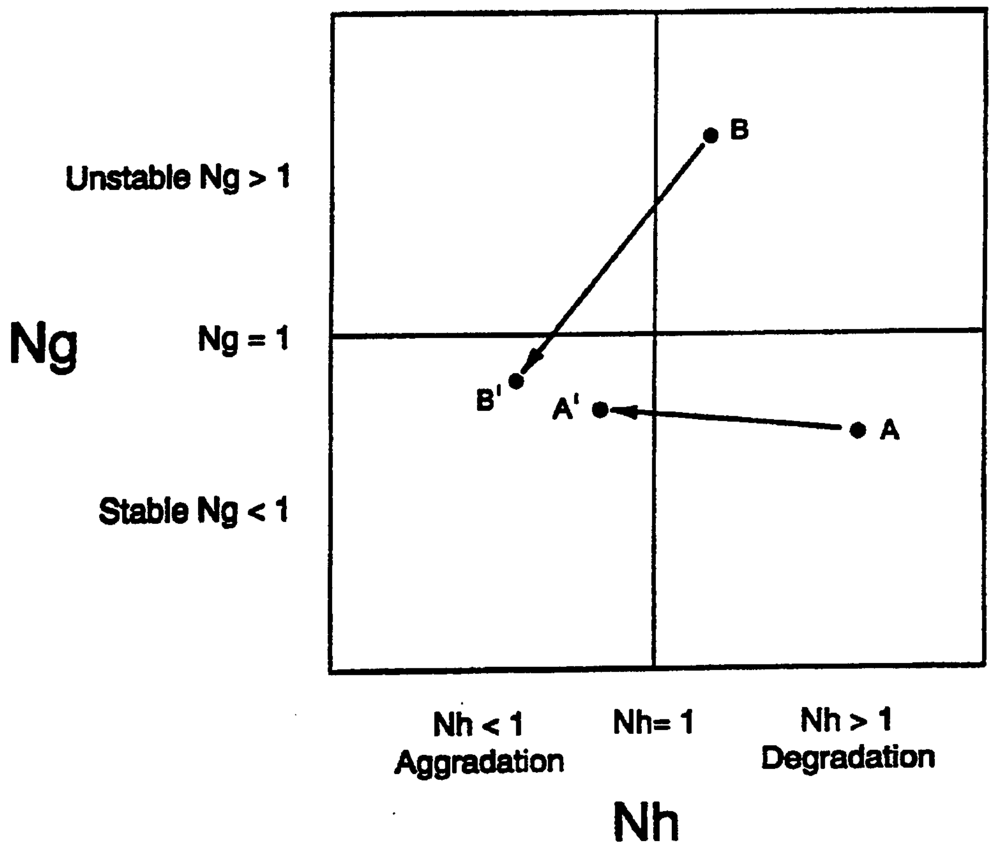


Figure 5. Sub-watershed channels of Hickahala Creek watershed plotted on an Nh/Ng diagram (after USAED Vicksburg, 1990)

SAM (USACE, 1993) is a flexible program for the computation of sediment transport at a section, sediment yield, channel roughness, and related computations. Copeland (1991) explained the analytical approach for using the SAM program, which couples resistance and sediment transport equations to solve for the channel dimensions of width, depth, and slope. A family of solutions for width and slope is computed that describes a series of width and slope combinations that provides for water and sediment continuity for a cross-section. SAM also provides for compositing several cross-sections within a reach to generate a reach-average condition.

Sediment transport modeling has three primary functions. First, the model is used to predict the locations of aggradation and degradation along the channel. Second, the model is used to determine the effective discharge, or range of effective discharges for the channel. The effective discharge or range of discharges are those that transport the majority of sediment and, therefore, do most of the geomorphic work in the channel (Wolman and Miller, 1960; Wolman and Gerson, 1978; Biedenharn et al., 1987; Watson et al., 1988). Third the model is used to determine the sediment yield from the watershed. Ideally, the sediment yield should be divided into channel and non-channel sources. In most of the Yazoo Basin

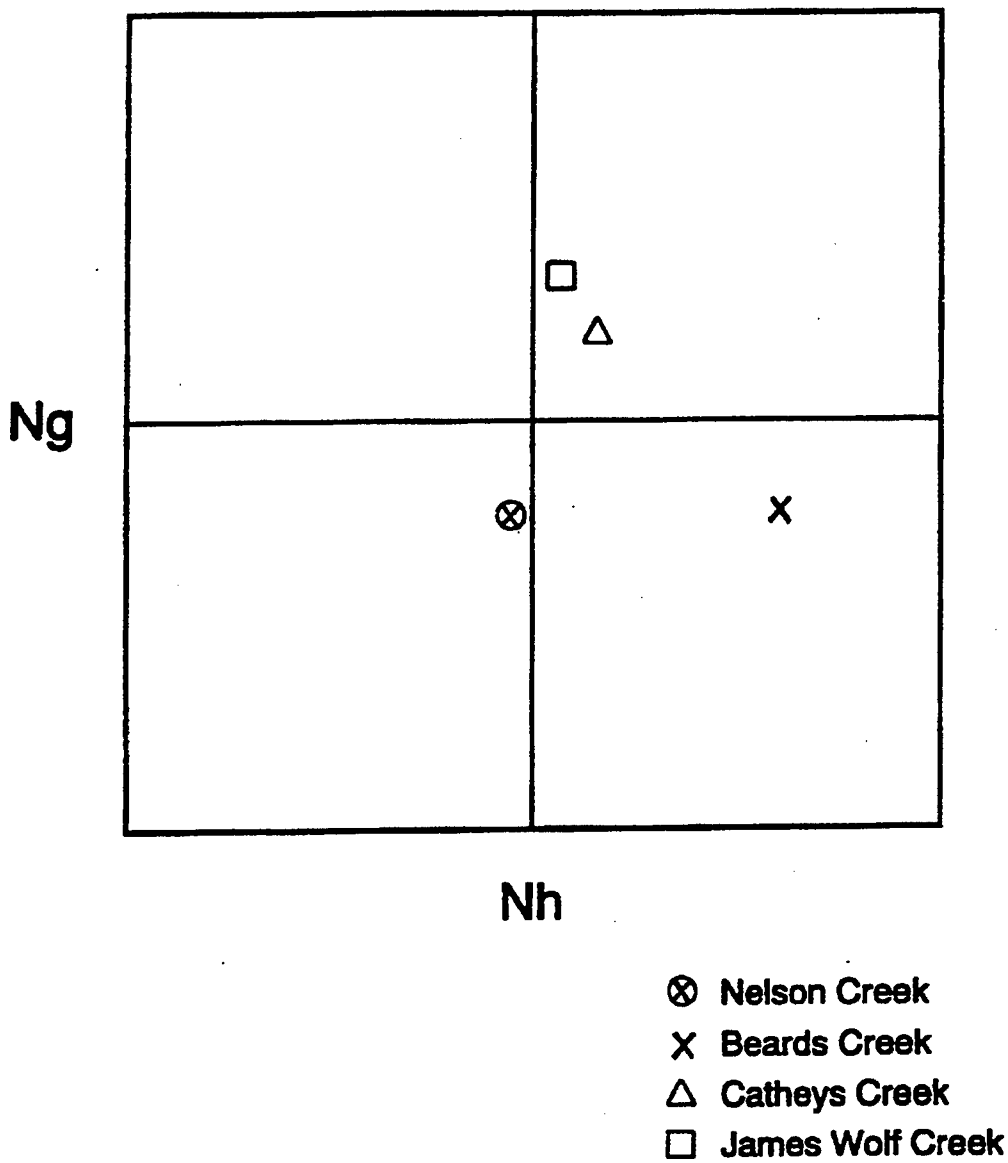


Figure 6. Dimensionless stability number diagram for stabilization measures on two hypothetical streams

watersheds, channel erosion produces the bulk of the sediment yield (Watson et al., 1986). The model also can be used to determine the reduction in sediment yield or the aggradation or degradation effects of any remedial measures.

Watson et al. (1995) used SAM (USACE, 1993) to demonstrate that stable channels in the Yazoo Basin of Mississippi typically have a sediment concentration of approximately 1000 mg/l during the two-year event. Based on the analysis, Watson recommends that when designing channel stabilization measures, a target sediment concentration of 1000 mg/l should be considered for the two-year event. Watson shows that channels with a sediment concentration in excess of 2000 mg/l are typically degradational in nature.

3 Channel Response

Monitoring Sites

The DEC monitoring program currently includes 23 sites and a total of 34 miles of streams. Many of the sites were channelized in the past and are now actively incising. Drop structures, chevron dikes, riprap, and bioengineered bank stabilization has been constructed at many sites to stabilize the channels. In addition, reservoirs and sediment basins are located within the drainage basins of several of the sites. The sites included in this project were selected to provide a representative cross section of all of the streams in the DEC project. The selection criteria included, channel planform, bed material grain size distribution, channel stability, types of channel rehabilitation, and sites of special interest. The location of the 23 sites is shown in Figure 1. Table 1 provides a summary of a select number of characteristics of each channel.

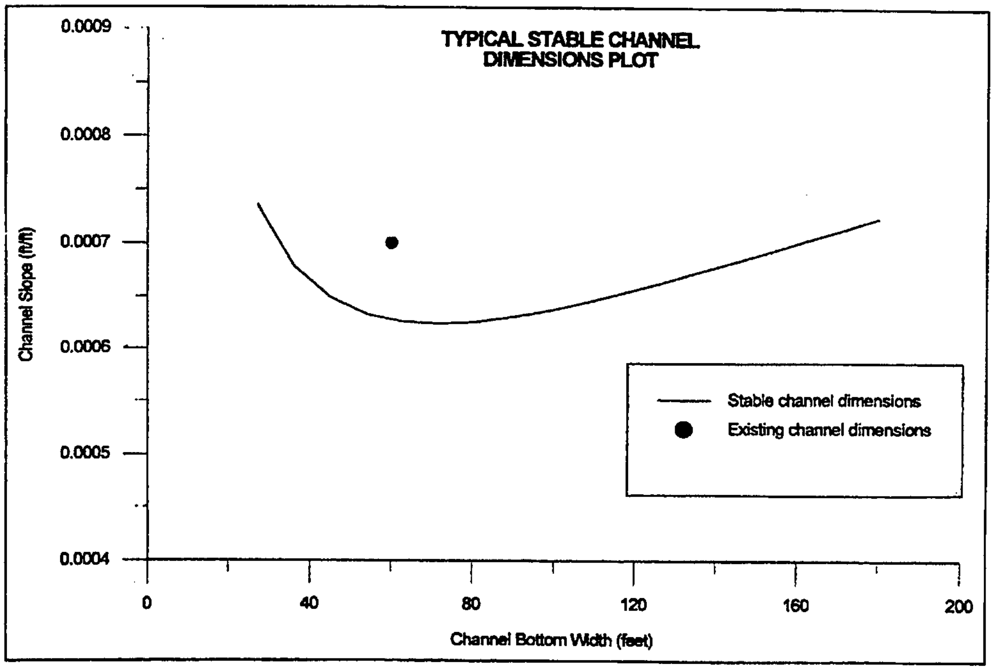
The following sections contain a brief description of each site. For each site, a drawing of the channel is presented along with a thalweg profile and tables which compare the results of the SAM and BURBANK analysis of the channel for 1993, 1994, and 1995.

SAM is used to compute the sediment transport capacity for the lesser value of the bankfull discharge or the two year event in each stream. Some of the streams have been subdivided into segments if there is a sudden change in the slope or bed elevation of the channel. The sediment transport capacity of each segment is computed. The average sediment transport capacity of streams that have desirable characteristics and appear to be stable was found to be 1000 mg/l. SAM was used to compute the stable channel dimensions for each segment. Stable channel dimensions are defined as the width and slope of a trapezoidal section that will transport the specified amount of sediment of 1000 mg/l for a given discharge. The angle of the banks of the trapezoidal section are assumed to be the same as the average bank angle of the channel. Figure 7 shows a typical stable channel dimension plot. The width of the channel is shown on the horizontal axis and the slope of the channel is shown on the vertical axis. The point of minimum slope on the curve is also referred to as the point of minimum stream power. The slope and width of an existing channel can then be described as a percentage of the minimum stable channel slope and width at the minimum stable channel slope. An existing channel with a width and slope of 100% each would then by definition be a stable channel. The degree to which the width and slope of a channel deviate from 100%, is an indicator of channel stability. For each channel segment, the slope as a percentage of minimum slope and width as a percentage of width at minimum slope is plotted. Each plot shows the dimensions for 1993, 1994, and 1995. A temporal trend in the data towards a width and slope of 100% indicates an increase in channel stability.

BURBANK computes the percentage of stream bank at risk of failure for slab and rotational failure for the banks of a channel (Burgi et al. 1995). The program obtains the channel geometry from a HEC-2 input deck and the soil properties from the user, to compute the stability of both banks at each cross section. The program then computes the percentage of bankline in a survey reach which has a factor of safety less than one. This percentage of the bank line is considered to be at risk. The program can also compute the percentage of bankline that would be at risk for a specified amount of bed degradation. A comparison of the BURBANK results for each stream are shown. A decrease in the percent bank at risk over time, indicates that the bank stability of a stream is increasing.

A table of information and a comparison of thalweg profiles are given for each site. Bank material, basin, and sediment properties for each site. For each segment, the average slope, width, depth, and sediment concentration at the smaller of the 2-year or bankfull discharge is given for each segment. Each segment also has been classified by Channel Evolution Model (CEM) type, stability, and the presence of bank stabilization or grade stabilization. For the purposes of this table, stability is defined as the absence of a significant trend to widen, narrow, aggrade, or degrade.

Figure 7. Typical stable channel curve with existing channel dimensions

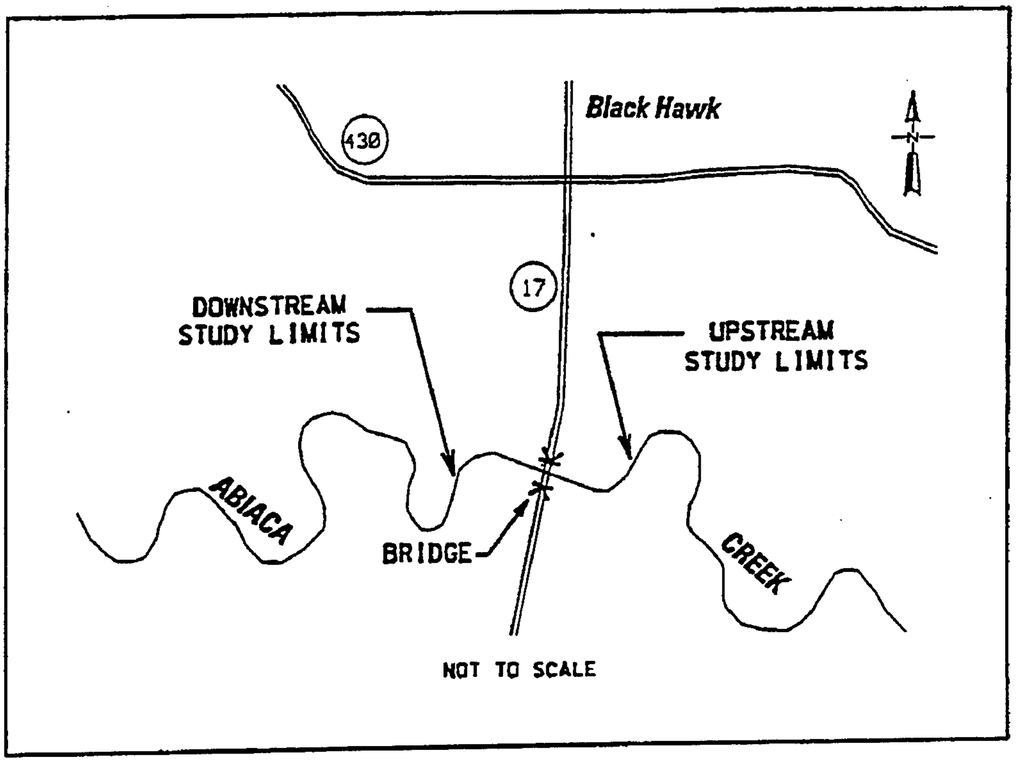


The CEM classification may not be applicable to each segment, for example in ponder segments upstream of grade control, and a zero (0) will be assigned if no CEM classification is appropriate. The results of SAM and BURBANK calculations are also presented for each segment.

Abiaca Creek, Site 3

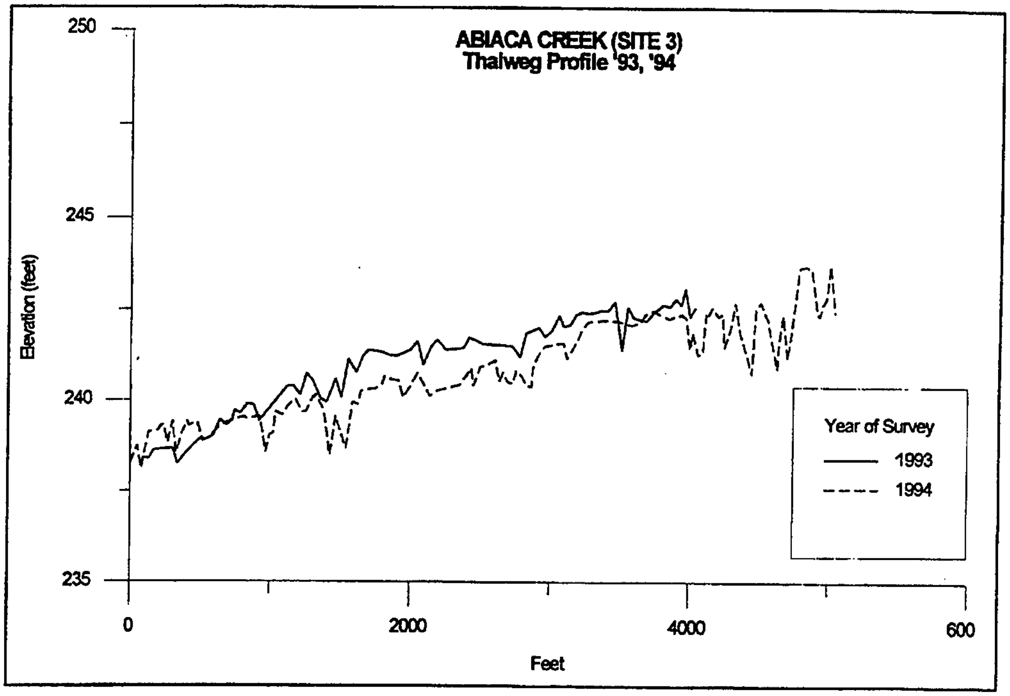
Site No. 3 is shown on Figure 8, and is located in T17N, R3E, Section 20 at the Highway 17 crossing of Abiaca Creek. The approximate watershed area at this site is 26.5 square miles. This site was selected because of the relative stability of the channel at this location, and is upstream of the gravel mining. The stream bed at Site No. 3 is comprised primarily of sand with minor amounts of gravel. The banks are generally well-vegetated with mature vegetation down to the low-water surface; however, erosion of the outside bank of the bendways was noted. Wind storms and ice damage has caused several debris affected reaches, which have caused local bank instability.

Figure 8. Abiaca Creek, site #3



BURBANK results (Table 2) confirm that the banks are stable for a friction angle of 14.7^0. With assumed saturated bank conditions, a friction angle of zero, only 6% of the bank is at risk. If 3 feet of degradation is assumed to occur, the risk of bank failure has decreased from 19% in 1993 to 12% in 1995. Comparison of the thalweg surveys indicate no significant aggradation or degradation trend (Figure 9). The reach is generally stable with no man-made bank or grade stabilization.

Figure 9. Thalweg profiles for Abiaca Creek, site #3



Abiaca Creek, Site 4

Site No. 4 is on Abiaca Creek and extends approximately 4,000 feet upstream from the confluence of Coila Creek as shown on Figure 10. This site is located in T17N, R2E, Section 4 and has a watershed area of approximately 44 square miles. This site is located approximately 1.8 miles downstream of a major sand and gravel processing operation that can be associated with increased supply of suspended and bed material load. Stream banks in this reach are relatively stable except as the channel impinges on high bluffs. The bed has fluctuated with a general aggradation for the past four years, and is a mixed sand/gravel reach. With the low summer and fall discharges, vegetation had encroached into the channel. No vegetation was observed to be permanently affecting the channel, and will be removed unless the low flow persists. See Table 3 for summary results and Figure 11 for thalweg profiles.

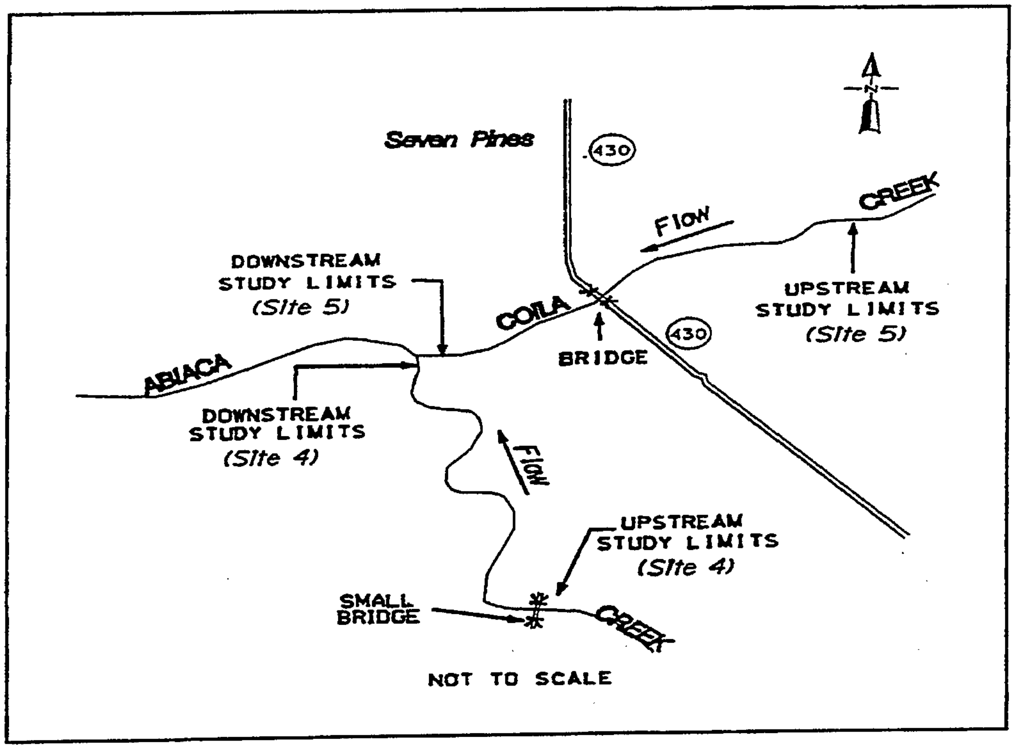


Figure 10. Abiaca Creek, site #4

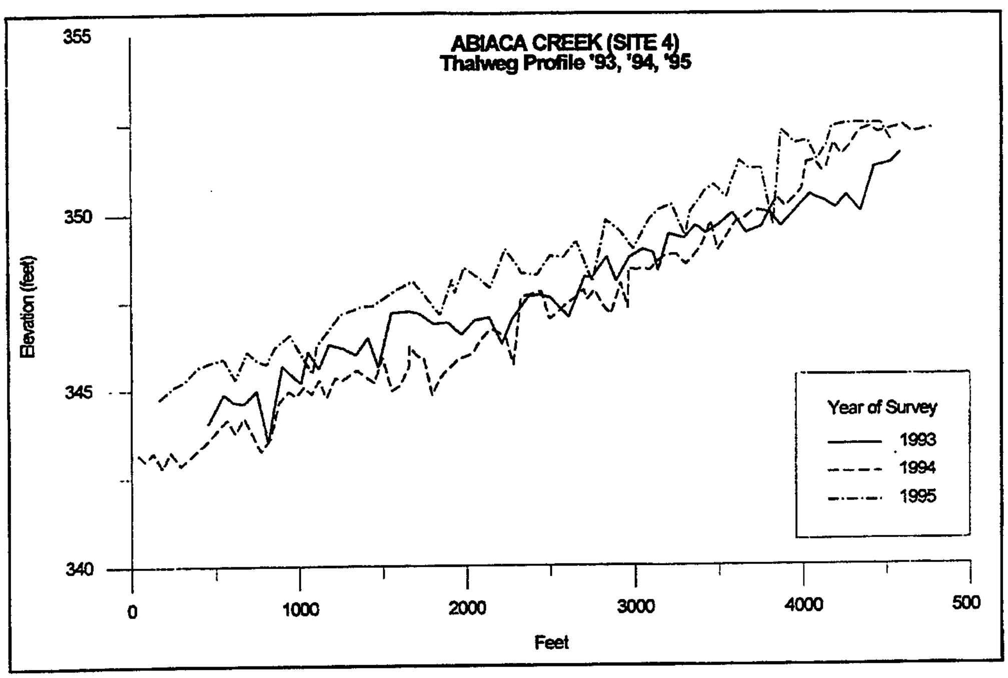


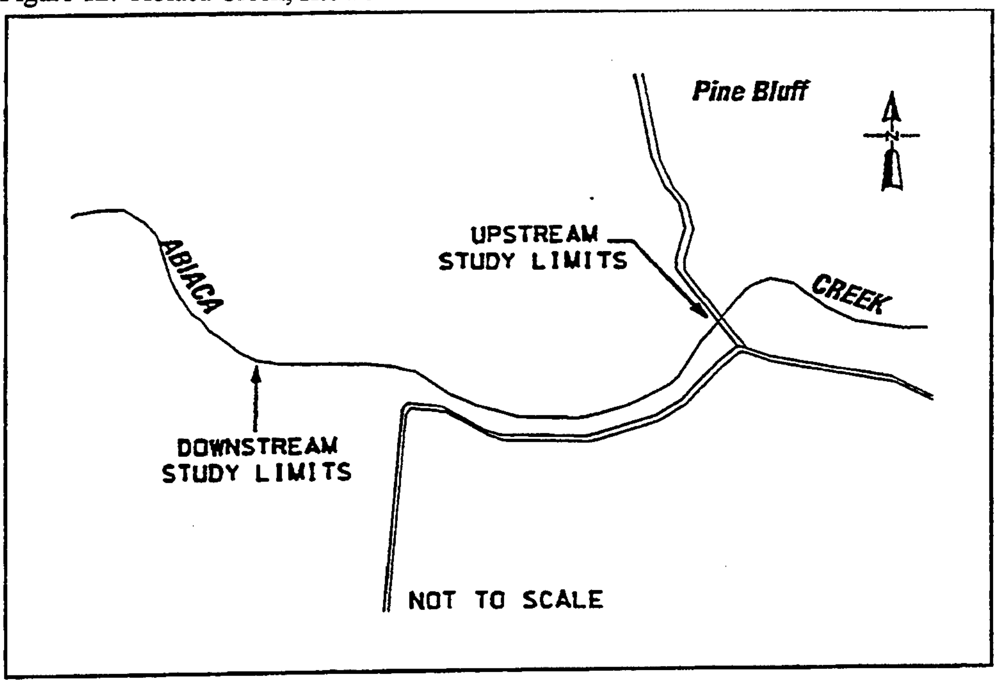
Figure 11. Thalweg profiles for Abiaca Creek, site #4

Abiaca Creek, Site 6

Site No. 6 is located on Abiaca Creek where the stream emerges from the hill line into the flatter Yazoo Delta in T17N, R1E, Sections 13 and 14, as shown on Figure 12. The drainage area at this location is approximately 99 square miles. This is also the site of the Pine Bluff gauging station with records from 1963 to 1980. This station has been reactivated and includes a pumped sediment sampler. The study reach extends approximately 4,000 feet downstream of the Pine Bluff gauging station.

The thalweg profile and channel dimensions have been relatively constant since 1992. A project to construct a sediment trap at this site was observed to be under construction in 1995. Later monitoring results will be impacted by that construction. See Table 4 for summary results and Figure 13 for the thalweg profiles.

Figure 12. Abiaca Creek, site #6



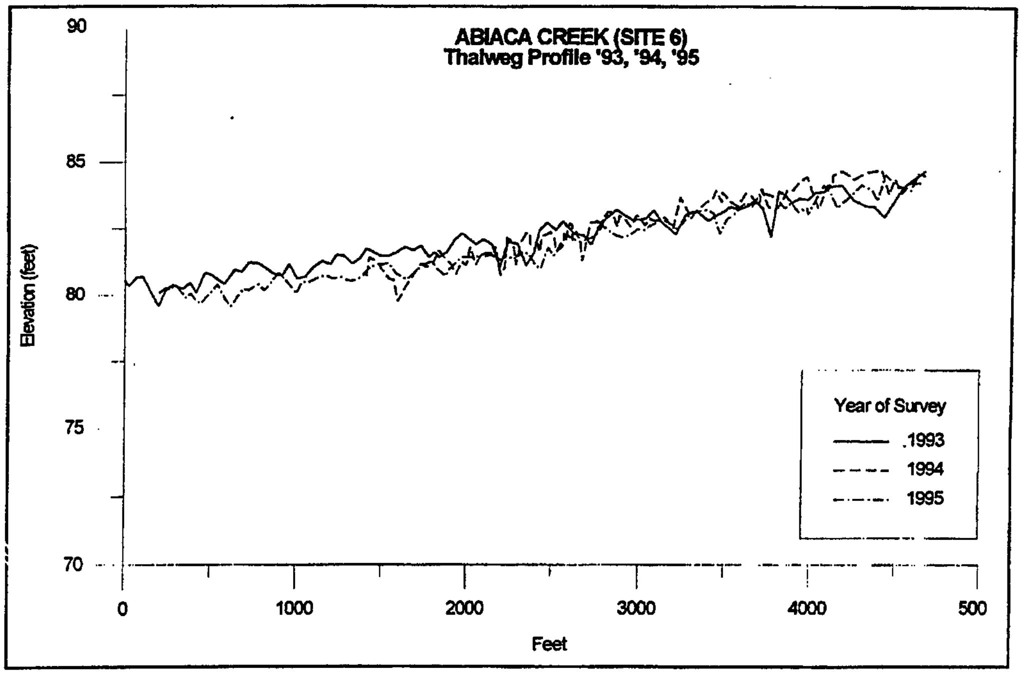


Figure 13. Thalweg profiles for Abica Creek, site #6

Abiaca Creek, Site 21

Site No. 21 is near the mouth of Abiaca Creek at Highway 49 as the stream enters the wildlife area. The Vicksburg District has designed a sediment trap basin for this location by setting the levees back and allowing frequent overflow of the stream. The construction of the sediment trap was observed to under construction at the time of the 1995 inspection. The reach is approximately 4,000 feet in length and is shown on Figure 14. See Table 5 for summary results and Figure 15 for thalweg profiles.

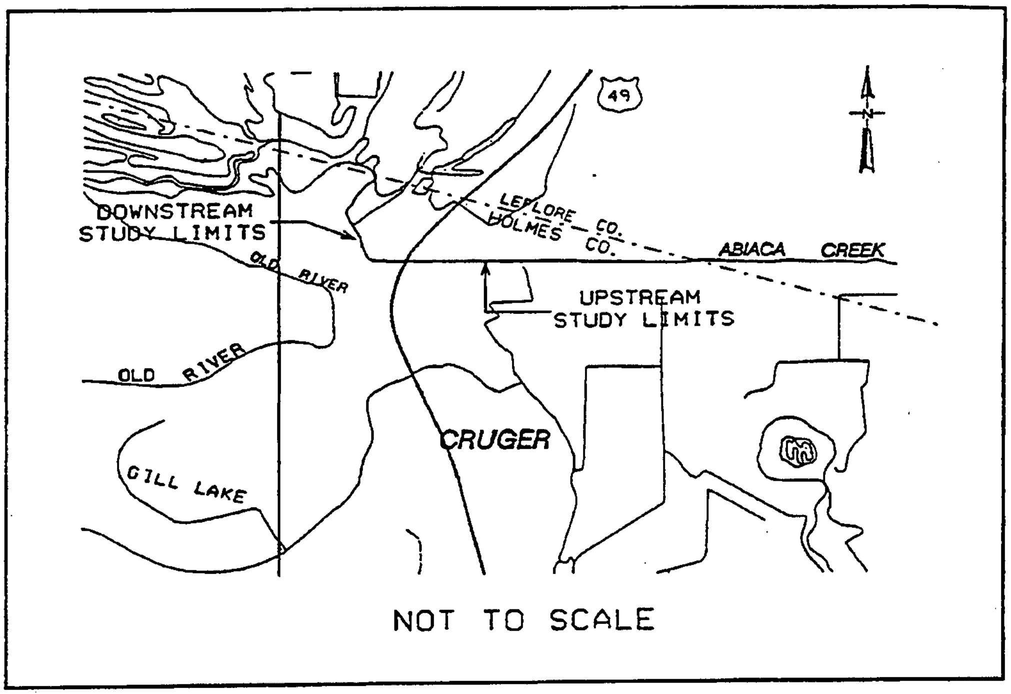


Figure 14. Abiaca Creek, site #21

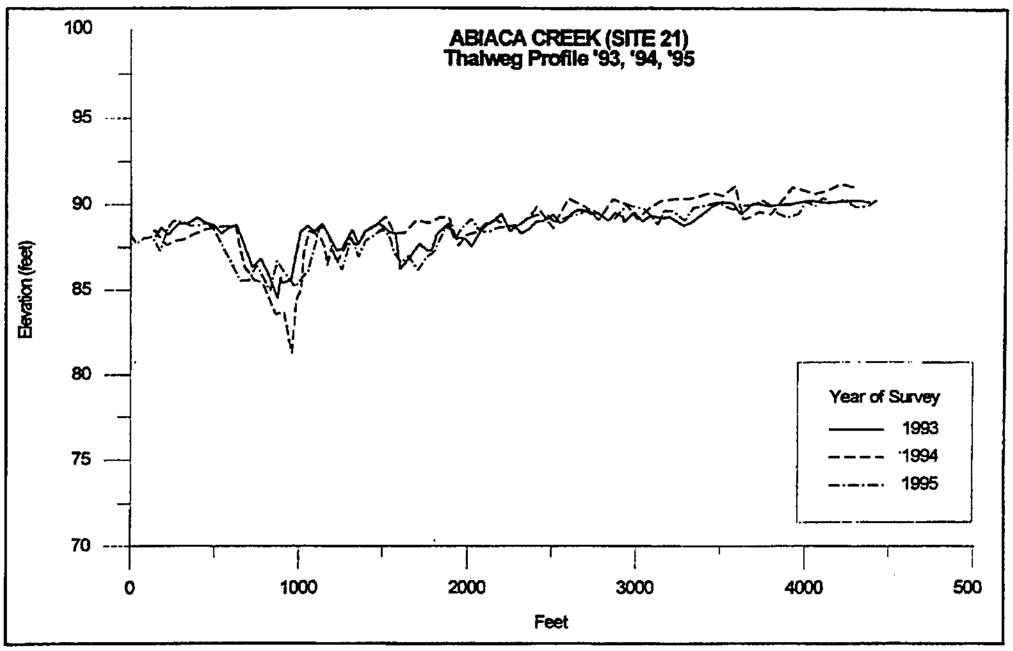


Figure 15 Thalweg profiles for Abiaca Creek, site #21

Burney Branch, Site 12

Site No. 12 is located on Burney Branch near Oxford, Mississippi. The study reach begins at the Highway 7 crossing of Burney Branch and extends downstream for a distance of approximately one mile through a reach containing two SCS high-drop structures as shown on Figure 16. Burney Branch has a drainage area of approximately 10 square miles at this location. The site can be located on the Oxford quadrangle map, T9S, R3W, Sections 4 and 9. See Table 6 for summary results and Figure 17 for thalweg profiles.

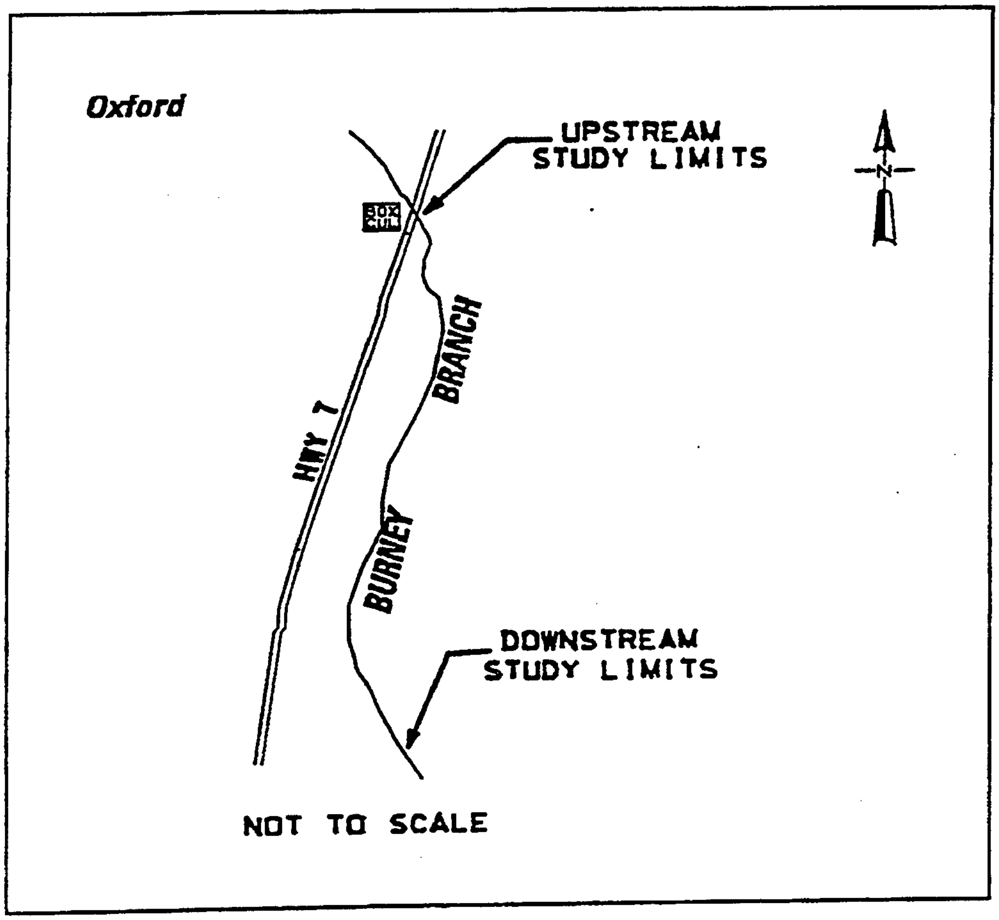


Figure 16. Burney Branch, site #12

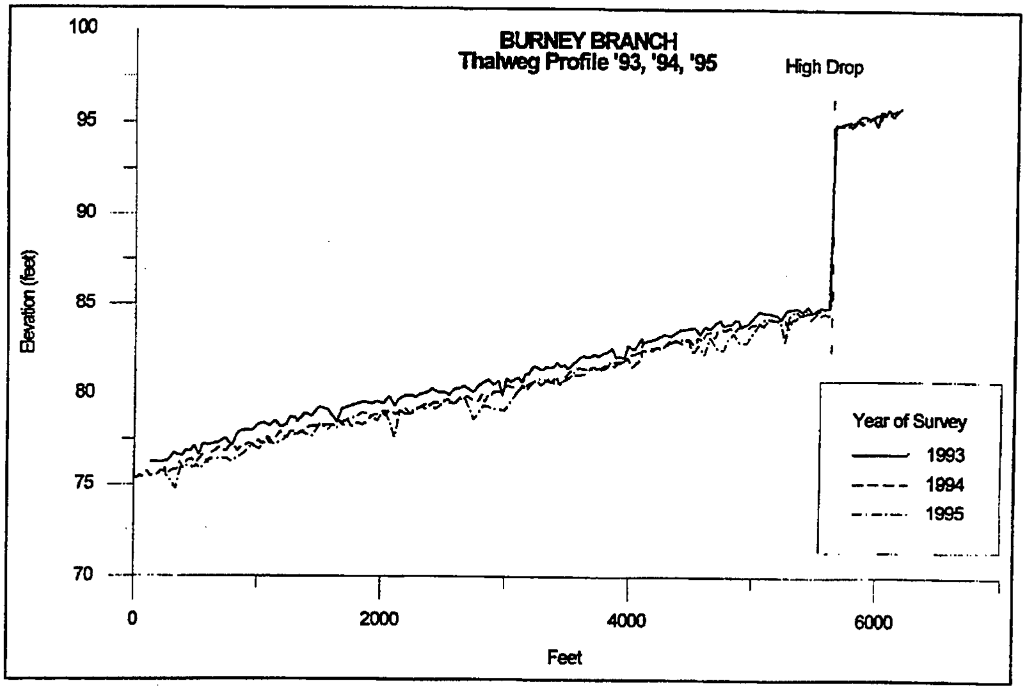


Figure 17. Thalweg profiles for Burney Branch, site #12

The two high-drop structures have been very successfully utilized in rehabilitating this reach of Burney Branch. Both structures were constructed in 1982 by the SCS, and the effects of the structures on the channel were surveyed and analyzed by Watson et al. (1984). These structures were designed to contain the 100-year discharge and include the provision for floodplain storage using valley dams in conjunction with each structure. The original design of the structures provided for a bed slope of 0.0008 between structures, based on Lane's tractive stress analysis. The 1984 surveyed bed slope was 0.0012, indicating that the upstream sediment yield was greater than planned. Since 1984, several major channel stabilization projects have been constructed upstream. Channel stabilization under conditions of decreasing sediment supply is a situation that will be faced as the success of the DEC programs are realized. Potentially, upstream stabilization can cause stability problems downstream.

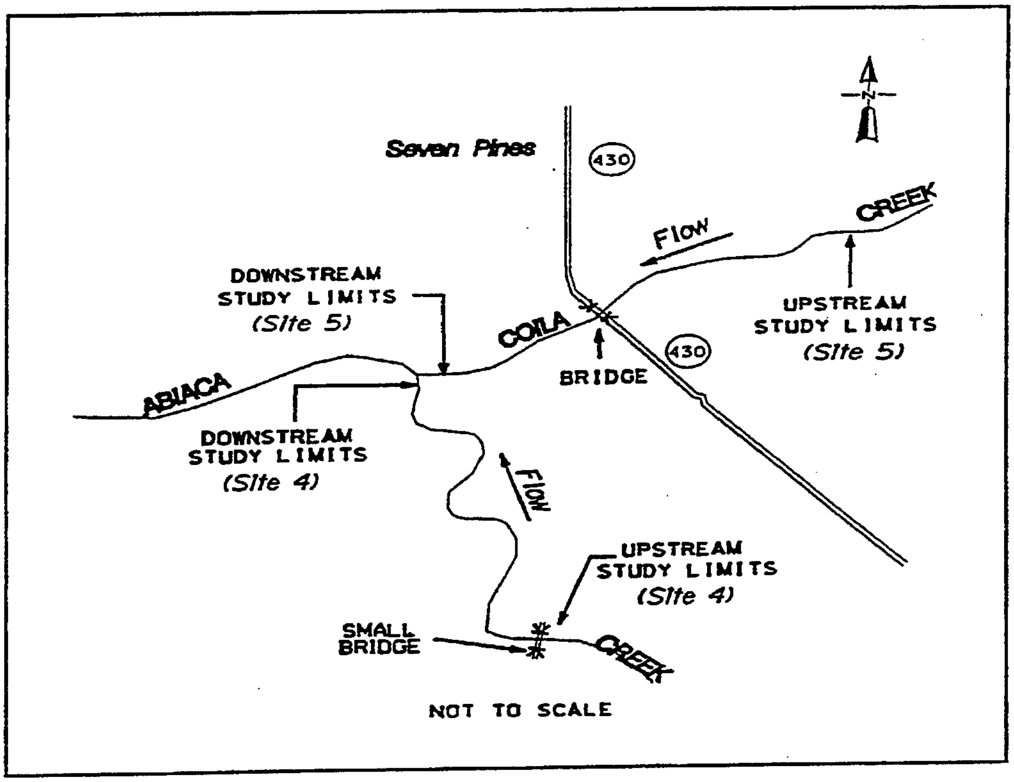
Segment 1 is a short, highly controlled reach located between a downstream high drop grade control and the upstream highway box culvert. Both banks have been stabilized for at least a portion of the segment length. Computation of the backwater characteristics within this short reach are primarily controlled by the downstream structure rating curve, and are uncertain for the purposes of the SAM results.

Segment 2 is stable, and is not significantly affected by bank stabilization. The downstream high drop structure, at Station 0+00, has been effectively designed. As shown by the SAM and BURBANK results, the channel is functioning at near minimum slope. The hydraulic slope is approximately the same as the 1984 surveyed value of 0.0012.

Coila Creek, Site 5

Site No. 5 is located on Coila Creek, a tributary to Abiaca Creek. The site extends upstream approximately 4,000 feet from the confluence with Abiaca Creek as shown on Figure 18 in T17N, R2E, Section 4. The site has a watershed area of approximately 42 square miles, very similar to Site No. 4, and allows the comparison of two almost equal size drainage basins. Coila Creek has a high proportion of the basin control by SCS reservoirs, and the gravel mines on Coila Creek are not as active as those along Abiaca Creek. See Table 7 for summary results and Figure 19 for thalweg profiles.

Figure 18. Coila Creek, site #5



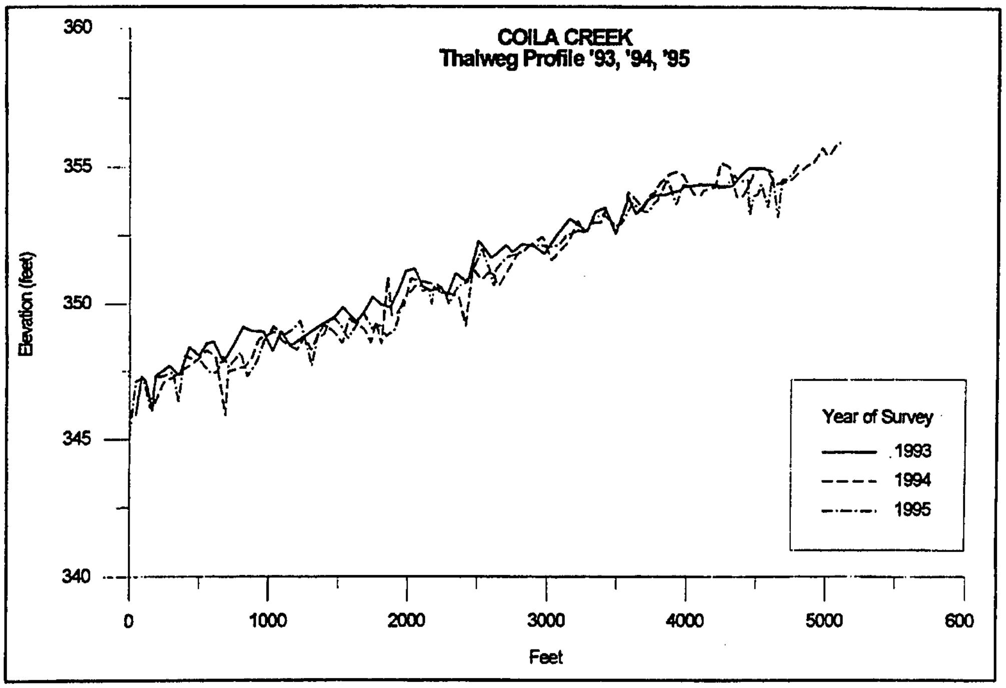


Figure 19. Thalweg profiles for Coila Creek, site #5

The reach thalweg profile has no significant trends, and the bank stability was poor only near the confluence with Abiaca Creek in a bendway. The D_{50} of the reach was sampled and analyzed to be 10 mm, which does not allow reliable SAM computations using the sand-bed based equations. The upper portion of the reach is has a very stable inner-channel with a gravel bed and overhanging riparian vegetation.

Fannegusha Creek, Site 2

Site No. 2 is located on Fannegusha Creek, also in the Black Creek watershed, and can be found on the Coila quadrangle map in T16N, R3E, Sections 1 and 2. As shown in Figure 20, the study reach is approximately 4,000 feet in length, 2,000 feet upstream and downstream of a county road bridge. The watershed area at the site is approximately 18 square miles. HEC-1 hydrology and HEC-2 hydraulics were developed by Northwest Hydraulics Inc. (1989). This reach was chosen as representing a very unstable sandbed channel. See Table 7 for summary results and Figure 21 for thalweg profiles.

A low-drop structure was constructed in 1993 approximately 1500 feet downstream of the bridge. The stream bed appears to be aggrading for a distance of approximately 1500 to 2000 feet upstream of the structure. The bridge was replaced in 1994 due to earlier channel widening. Observations indicate that the channel will continue to widen as over-steepened banks continue to fail, due to previous bed degradation.

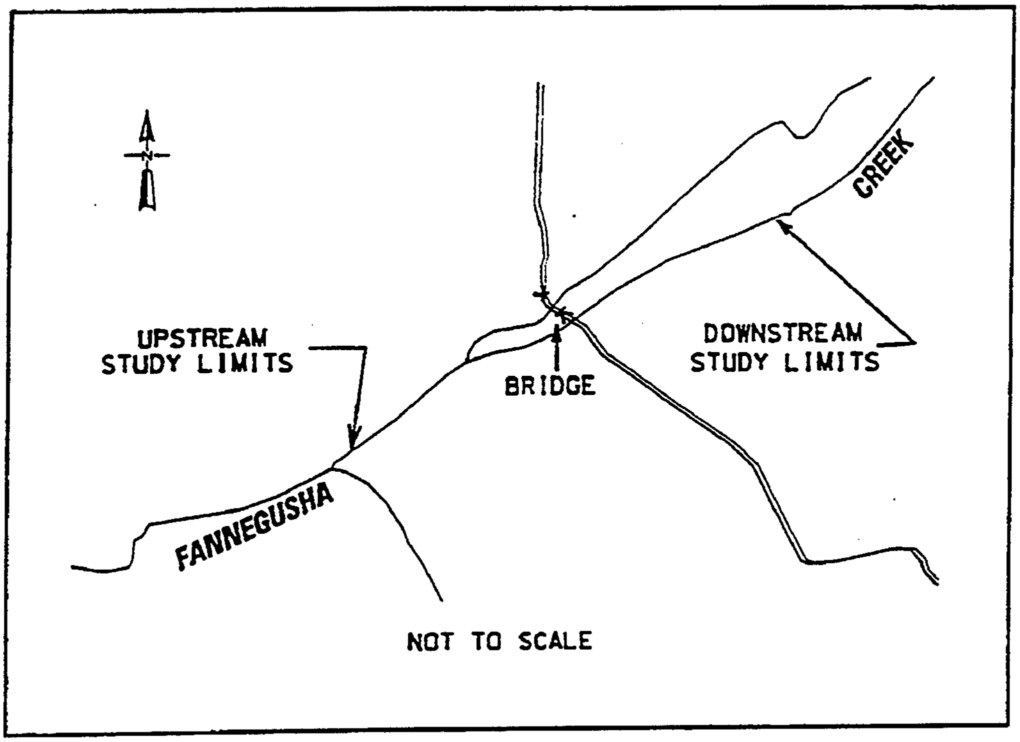


Figure 20. Fannegusha Creek, site #2

Bed degradation upstream of the bridge will continue as a headcut progresses upstream. At present, the headcut is located approximately 1200 feet upstream of the bridge. Another grade control structure has constructed upstream of the study reach; however, the primary sediment supply to the reach may be entering the channel in a large left bank tributary that is near the upstream extent of the study reach. An investigation of this tributary is recommended for the purpose of developing stabilization plans.

BURBANK results (Table 8) indicated the banks are generally stable. The reach averaged SAM results portray a generally stable hydraulic condition; however, the channel response to the recently constructed grade control structure is very dynamic and continue upstream. Although the upstream portion of the study reach is a CEM 2, the overall reach has been classified CEM 4.

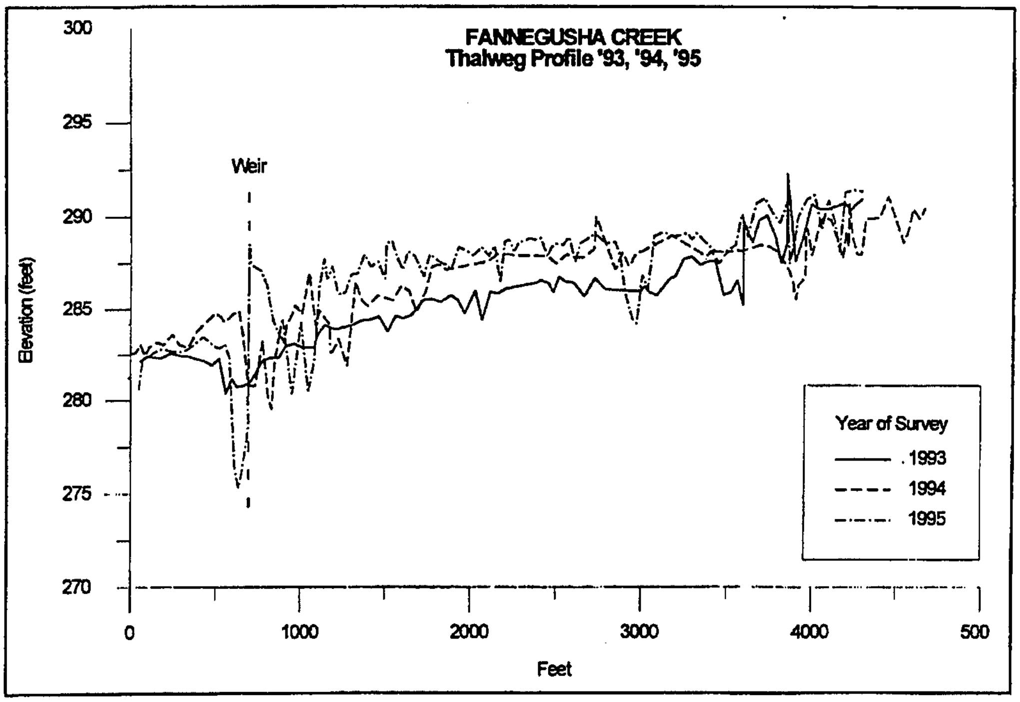


Figure 21. Thalweg profiles for Fannegusha Creek, site #2

Harland Creek, Site 1

Site No. 1 is located on Harland Creek in the Black Creek watershed. The site is near Eulogy, Mississippi, and can be found on the Lexington quadrangle map in T14N, R1E, Section 22 and 27. Harland Creek is a mixed, sand and gravel bed stream, exhibiting some of the original meandering tendency shown on the map, Figure 22. The study reach is approximately 4,000 feet in length, 2,000 feet upstream and downstream of the county road bridge. The stream is unstable, with bank erosion and significant channel widening. Several areas of massive bank failures were identified, and these failure sites, along with bed and bank erosion, provide a high sediment yield to the downstream. See Table 9 for summary results and Figure 23 for thalweg profiles.

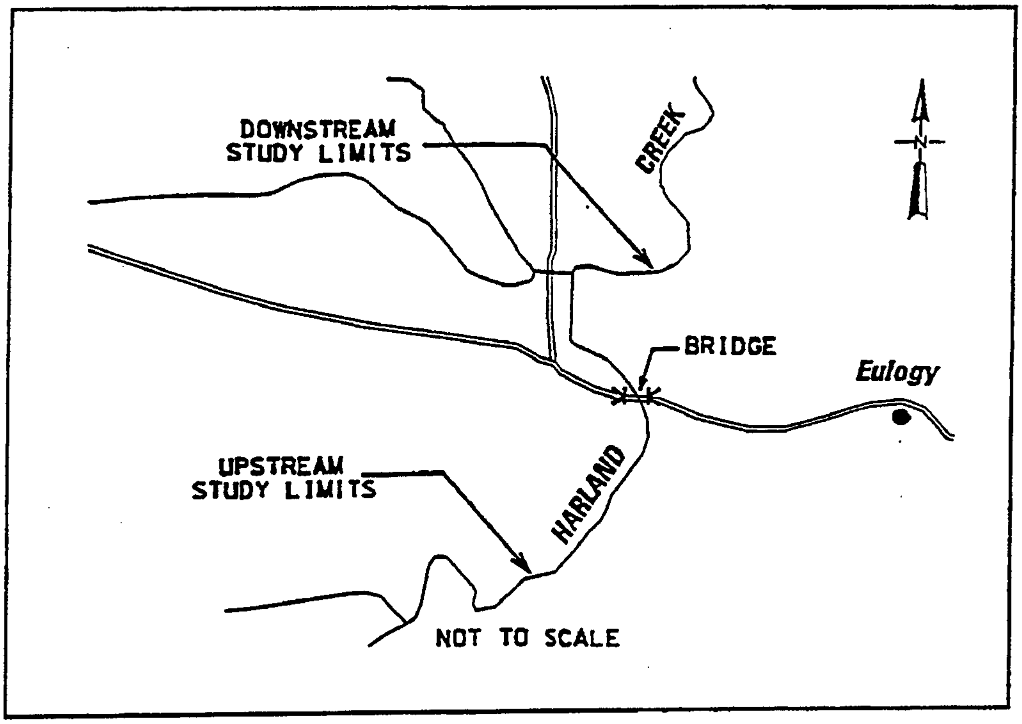


Figure 22. Harland Creek, site #1

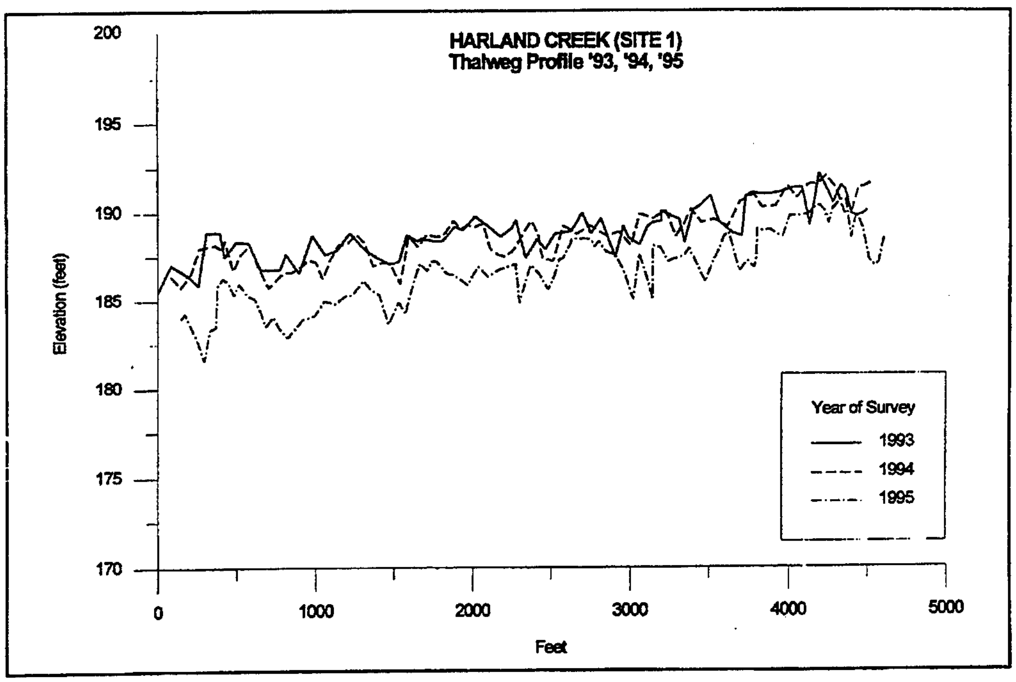


Figure 23. Thalweg profiles for Harland Creek, site #1

The site was chosen because of the mixed bed load, the fact that surveys were made before and after riprap stabilization measures were constructed in the reach, and a major reservoir is planned immediately upstream of the site. Presently, stream gaging in the reach is installed. The watershed area at the site is approximately 27 square miles. HEC-1 hydrology and HEC-2 hydraulics were developed by Northwest Hydraulics Inc. (1989). Portions of the study reach were surveyed during 1991 for construction of bank stabilization construction planning. The 1992 field data will allow a comparison of the existing conditions with the previous contractor analyses, and provides a baseline of field information for comparison with the 1993,1994, and 1995 surveys, which were made after the channel stabilization was constructed.

The thalweg profile (Figure 23) for the reach indicates a consistent degradation along the reach. Field evidence indicates that the reach has degraded, and significant bank erosion was noted. The longitudinal riprap placed in the lower 2000 feet of the reach experience minor launching, and no bank instability was noted along the riprap. The upstream, unprotected, portion of the reach had severe and consistent bank erosion, demonstrating the effectiveness of the downstream riprap. Additional bank stabilization for Harland Creek should be considered. A short gap in protection on the left bank downstream of the left bank tributary should be considered for construction.

BURBANK results (Table 9) indicate that the banks are generally stable, reinforcing the previous years conclusion that the observed instability is due to hydraulic forces, not geotechnical failure. With the sand-gravel, mixed bed (D_{50}=0.5 mm), the SAM results for slope are not valid. Minimum slope calculations tend to be too high, an observation at Harland 1 and 23, Abiaca 4, and Coila, all mixed-bed reaches.

Harland Creek, Site 23

From the previous site, the next county road bridge downstream is near the upstream extent of the Harland Creek-Willow Post site (Figure 24). The site continues downstream for approximately two miles to the next county road bridge and encompasses an intensive bank stabilization treatment of willow posts and upstream angled rock dikes. The rock dikes are referred to as bendway weirs. See Table 10 for summary results and Figure 25 for thalweg profiles.

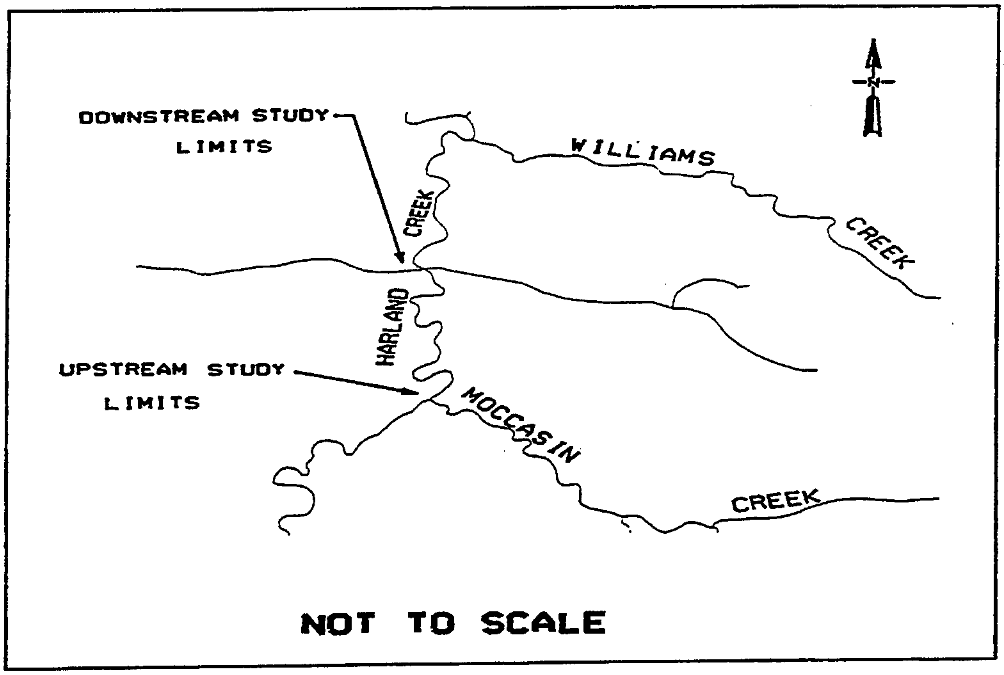


Figure 24. Harland Creek, site #23

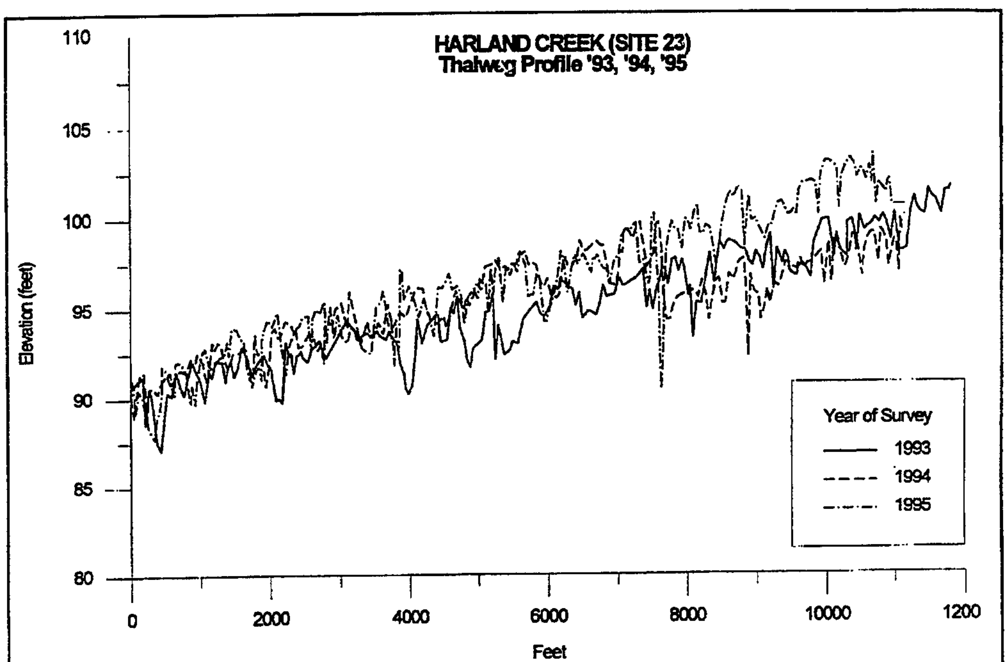


Figure 25. Thalweg profiles for Harland Creek, site #23

As shown in the thalweg profile, Figure 25, the primary difference between the

1993 and 1994 profiles is the aggradation that has occurred from about station 35+00 upstream to approximate station 75+00. The 1995 thalweg profile indicates that the aggradation has continued to move upstream, from approximately 75+00 to the upstream end of the 1995 survey.

Large gravel bars were observed in the field inspection of October, 1994. Some of these bars were in atypical positions for a meandering stream, indicating that the deposits occurred during the recession of a major flood event. It is expected that lower flows will continue to re-work these deposits. Two additional factors that may contribute to the aggradation is the degradation of the upstream site, and the increased roughness caused by the bendway weirs and the willow posts.

As with the previous Harland Creek Site 1, the SAM results are apparently unreliable for streams with a high percentage of gravel bed material (Table 10). BURBANK results indicate that the banks are generally stable, with only 2% of the bank at risk (Table 10). However, local erosion of unprotected bank is common.

Hickahala Creek, Site 11

Hickahala Creek is a major tributary to the Coldwater River with a drainage area of approximately 230 square miles at the confluence with the Coldwater. Simons, Li & Associates (SLA) conducted field reconnaissance, developed HEC-1 hydrology and HEC-2 hydraulics, and conducted sediment transport analyses for the Vicksburg District in 1987. The hydraulic computations were prepared based on channel geometry from 1968 and 1985 surveys. Construction related surveys have also been conducted on upper Hickahala Creek. USGS stream gauge records are available near the mouth of the watershed.

Site No. 11 is located in the upper watershed of Hickahala Creek, and has a watershed area of approximately 9 square miles. The site is located on the Tyro quadrangle map in T5S, R5W, Sections 2 and 3, a portion of which is shown as Figure 26. The site begins at a county road bridge and extends downstream to the confluence with the South Fork, and continues downstream on Hickahala Creek for approximately 1000 feet. The total study reach is approximately 4000 feet in length and includes two existing structures. A third structure is located on the South Fork about 700 feet upstream of the confluence with Hickahala creek. The lower portion of the study reach is actively incising into a cohesive clay bed. The upstream portion of the study reach is relatively stable with a sand bed. The reach was selected to monitor the response of the structures. See Table 11 for summary results and Figure 27 for thalweg profiles.

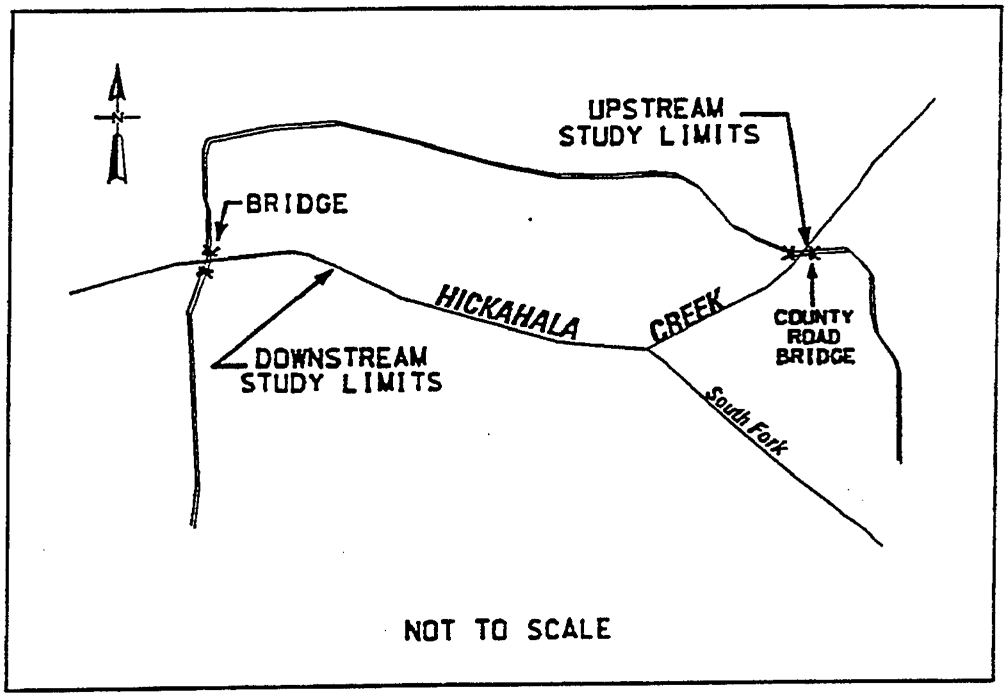


Figure 26. Hickahela Creek, site #11

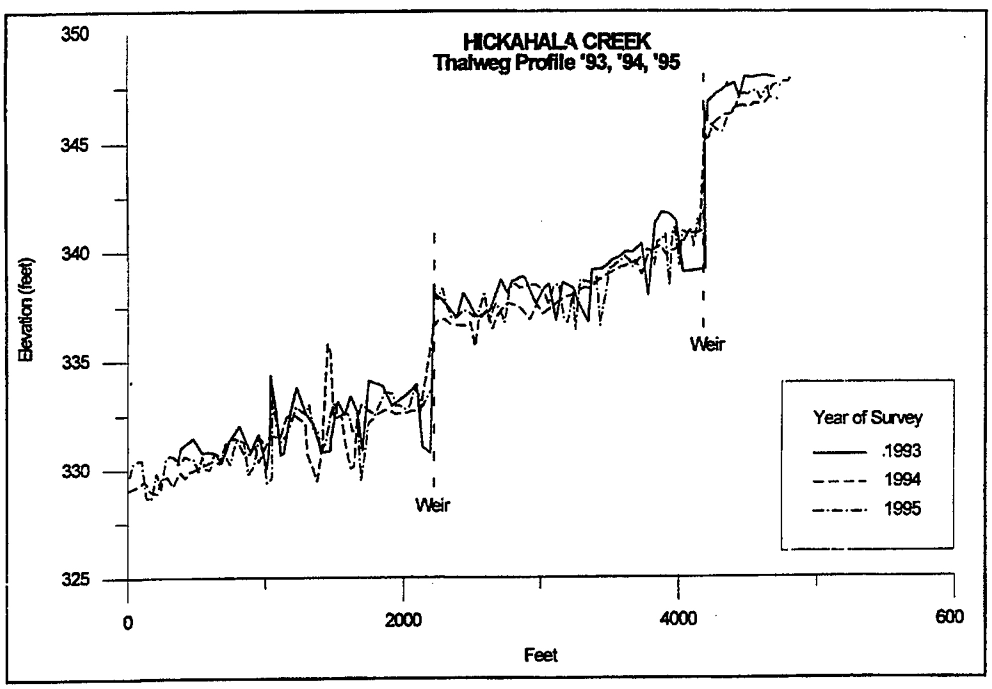


Figure 27. Thalweg profiles for Hickahela Creek, site #11

The downstream portion, Segment 1, is not influenced by a downstream grade control, although County bridge construction at the time of the last inspection may provide some control. The bed of Segment 1 is the erosion resistant clay commonly found at knickzones, and has been classifies as CEM 2. The thalweg profile indicates that the bed is eroding very slowly (Figure 27). Some filling was observed in Segment 2 as a result of the downstream grade control structure.

SAM results indicate that hydraulic slope is continuing to increase and to narrow, and BURBANK results indicate that the banks are stable for the conditions tested for Segments 1 and 2 (Table 11). Segment 2 should continue to respond to the structure with filling in the lower and middle portion of the segment, and the upper portion may degrade at the upstream structure lower apron. Segment 1 will continue to slowly erode until the clay material is breached, at which time headcutting with resume. At the time of the last inspection, an active headcut was observed in the upper portion of Segment 1.

At the present time, the site is unstable and is responding to the existing grade control structures. The structures are performing as designed to halt migration of the incision to the upper watershed.

Hotopha and Marcum Creek, Site 13

Site No. 13 is located on Hotopha Creek, west of Oxford, Mississippi. As shown in Figure 28, the site encompasses approximately two miles of Hotopha and Marcum Creeks and is located on the Sardis quadrangle map T9S, R6W, Sections 1 and 2, and in T9S, R5W, Section 6. The watershed area at the site on Hotopha Creek is approximately 17 square mile. A USGS gauging station is located at the Highway 35 bridge crossing of the Creek several miles downstream of the site. The study reach includes the confluences of Marcum Creek and Deer Creek with Hotopha Creek. A low-drop is located at the downstream extent of Hotopha Creek, a high-drop is located immediately upstream of the Highway 315 bridge, and a high-drop is located on Hotopha Creek immediately downstream of the confluence with Marcum Creek. Two low-drops are situated on Deer Creek, and one low-drop is located on Marcum Creek approximately 800 feet upstream of the confluence with Hotopha Creek. A third high drop has been constructed upstream of the site. WES-installed stream gauging is available at the high-drop near the confluence of Marcum and Hotopha Creeks. See Table 12 for summary results and Figure 29 for thalweg profiles.

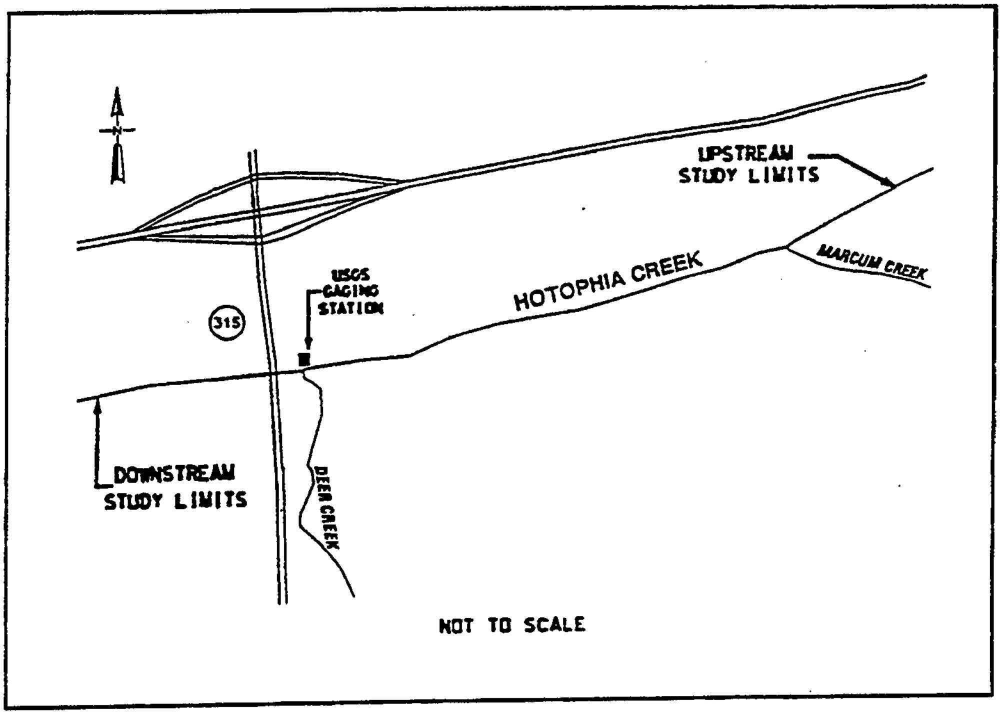


Figure 28. Hotopha and Marcum Creek, Site #13

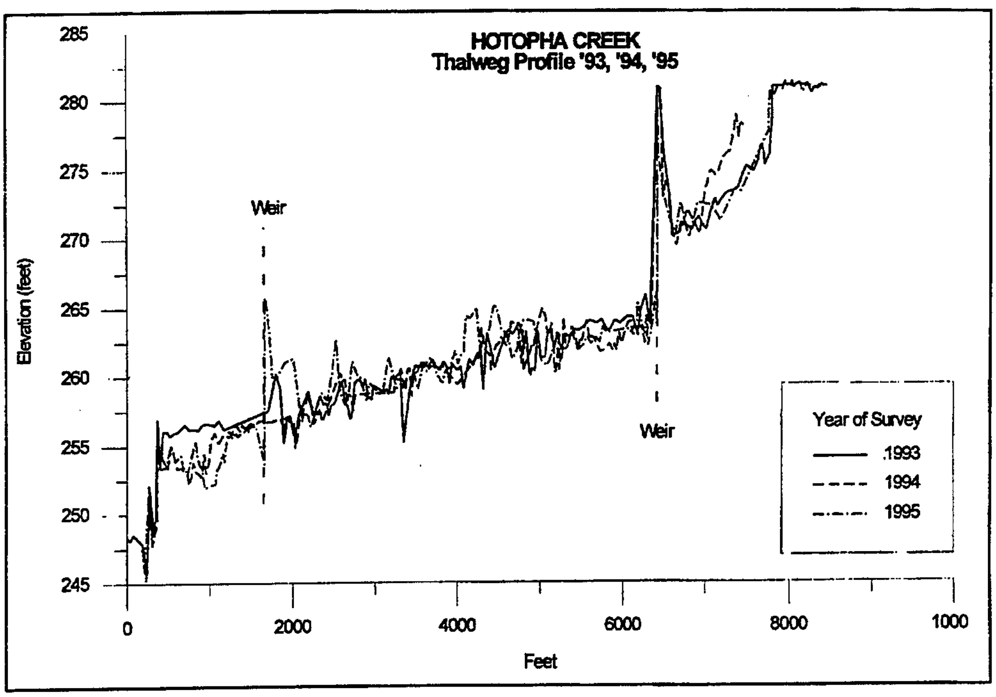


Figure 29. Thalweg profiles for Hotopha Creek, Site #13

Hotopha Creek was channelized in 1961, and was surveyed by the District in 1985. Water Engineering & Technology, Inc. (WET) conducted field reconnaissance in 1986 and prepared HEC-1 hydrology and HEC-2 hydraulics. This site is important because of the complexity of the various constructed elements, and the need to document channel response to the high-drop grade control. In addition, data from Burney Branch and Hotopha Creek provides the opportunity for a comparison of data from adjacent watersheds.

The thalweg profile, Figure 29, indicates that degradation is occurring in Segment 1, and is moving upstream to the downstream high drop. This incision is in response to sediment storage in the upstream structures. The surveyed profile indicates that some filling has occurred in Segment 2, and that very little filling occurred in segment 1. The three high drop structures and the upstream drop box culvert have provided massive sediment storage and pooling of water, and the response to these structures will occur slowly. The pools upstream of the high drop may persist for several years, and biological sampling could document the changes in habitat as the pools evolve.

All three segment have been classified as unstable, and each segment is ponder by the downstream structure. Segment 1 is degrading in response to the reduction in upstream sediment supply, and segments 2 and 3 are filling slowly. No CEM classification was made due to ponding, which was not a condition envisioned in the original model. The SAM calculation of the sediment transport capacity for Segment 1 is 3.5 times the capacity for Segment 2, and Segment is 1.6 times the Segment 2 capacity. Therefore, Segment 1 will degrade and Segment 2 will continue to aggrade if sediment supply is available. BURBANK results indicate bank instability can be expected, especially if the zero friction angle assumption occurs (Table 12).

James Wolf Creek, Site 19

Site No. 19 is located in the Hickahala Creek watershed on James Wolf Creek. At this location, James Wolf has a drainage area of approximately 11 square miles; however, it is extremely deep and wide. The site is located on the Tyro quadrangle map in T5S, R5W, Section 28. The study reach is shown on Figure 30, and extends downstream of the east-west county road for a distance of approximately 4,000 feet encompassing a low-drop structure. This low-drop structure appears to be stabilizing the bed of the stream; however, the banks remain unstable due to the significant depth. The stream is sand bed and at low flow conditions, the channel may be dry. The drop structure on the James Wolf Creek monitoring reach has required significant repair since construction and was rebuilt in 1995. Two additional drop structures were constructed on James Wolf Creek downstream of the monitoring reach during 1993 and 1994, and the downstream portion of the reach was stabilized in 1995 using longitudinal riprap. See Table 13 for summary results and Figure 31 for thalweg profiles.

The thalweg profile indicates that both segments degraded on the order of 1 to 2 feet (Figure 31). Sediment transport capacity in the range of 3000 mg/l and the channel slope, 0.0017, are approximately the same for both segments. BURBANK results based on surveys prior to the longitudinal riprap emplacement indicate that Segment 1 banks are 100% at risk, and that Segment 2, upstream of the structure, are 50% to 60% at risk. The Segment 1 bank stabilization should improve stability. SAM results indicate that the channel is relatively steep and wide at the 2-year discharge (Table 13).

Rebuilding the drop structure and downstream longitudinal riprap improves the stability of this system. Kudzu will continue to dominant the vegetation, restricting development of more desirable vegetation that could improve bank stability and increase roughness. However, channel response is slow and the rate of change is dependent on upstream sediment supply.

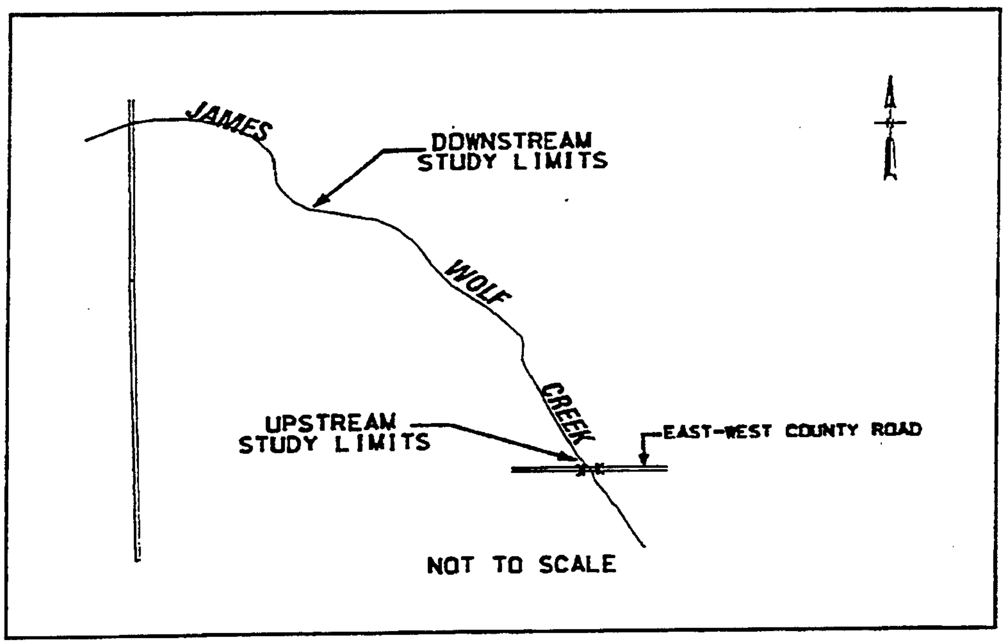


Figure 30. James Wolf Creek, site #19

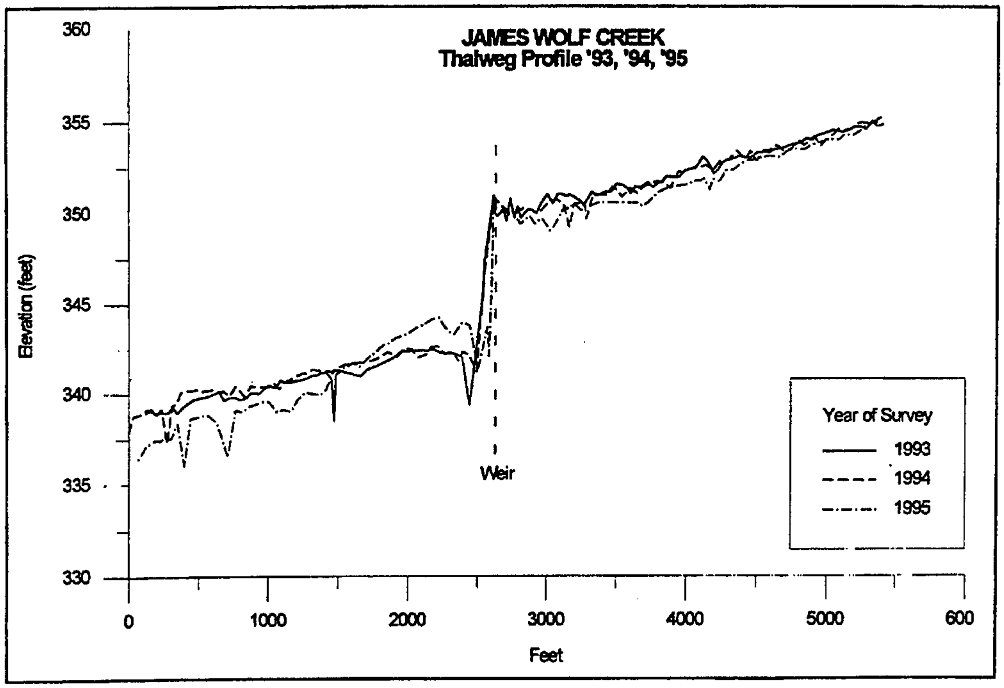


Figure 31. Thalweg profiles for James Wolf Creek, site #19

Lee Creek, Site 10

Site No. 10 is on Lee Creek in the Coldwater River basin, approximately 6 miles north of Victoria, Mississippi. The site can be located on the Byhalia quadrangle map in T2S, R4W, Sections 9 and 10. As shown in Figure 32, the study reach extends approximately 2,000 feet upstream and downstream of the Highway bridge. The channel is relatively stable and is transporting minor amounts of gravel in a sand bed. Upstream of the bridge, the channel exhibits some meandering and apparently has not been channelized. Downstream of the bridge, the channel is stable with mature, 14-inch diameter trees near the low-water surface. The remnants of spoil

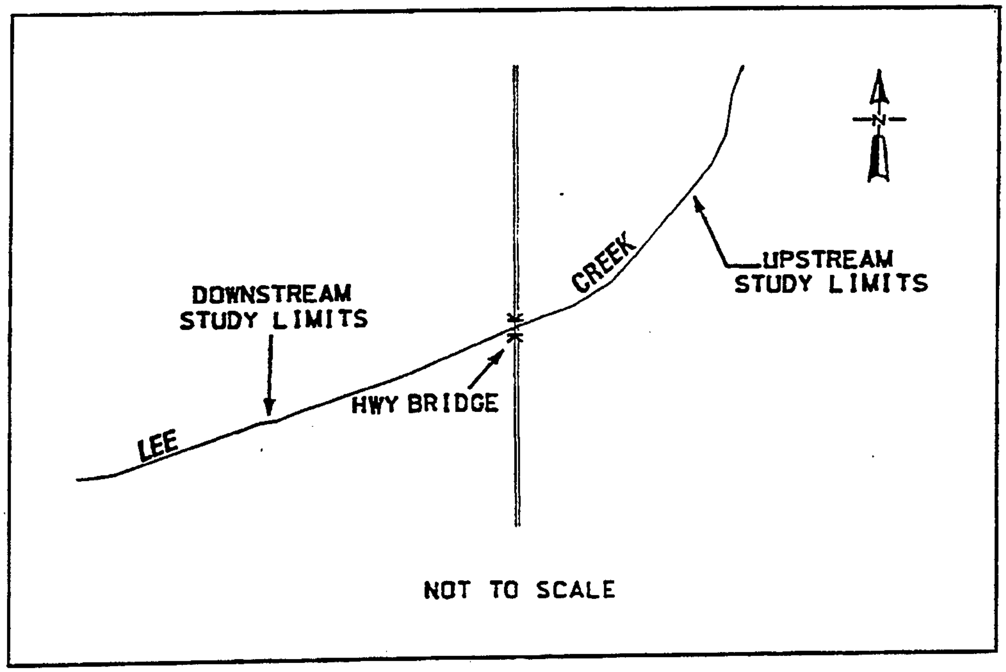


Figure 32. Lee Creek, site #10

piles indicate that downstream of the bridge, the channel has been channelized. This reach provides an excellent opportunity to document a stable, channelized, sand-bed stream. See Table 14 for summary results and Figure 33 for thalweg profiles.

During October, 1994 discussions with Mr. John Kearl, the property owner at the site, he requested a drop pipe be considered for the left bank in the filed upstream of the site. He also alluded to the loss in conveyance at the site. The upstream channel banks are in a cotton field and are covered with kudzu. Debris and willow trees in the channel have formed divided flow reaches in the upstream portion of the reach. Consideration should be given to eradicating the kudzu, channelization, and re-vegetation. The downstream channel has little kudzu due to cattle feeding, birch trees along both banks, and have better conveyance and stability.

BURBANK results indicate confirm that the banks are stable. SAM results indicate that the slope has changed little since 1993, however, average width is decreasing due to upstream loss of conveyance (Table 14).

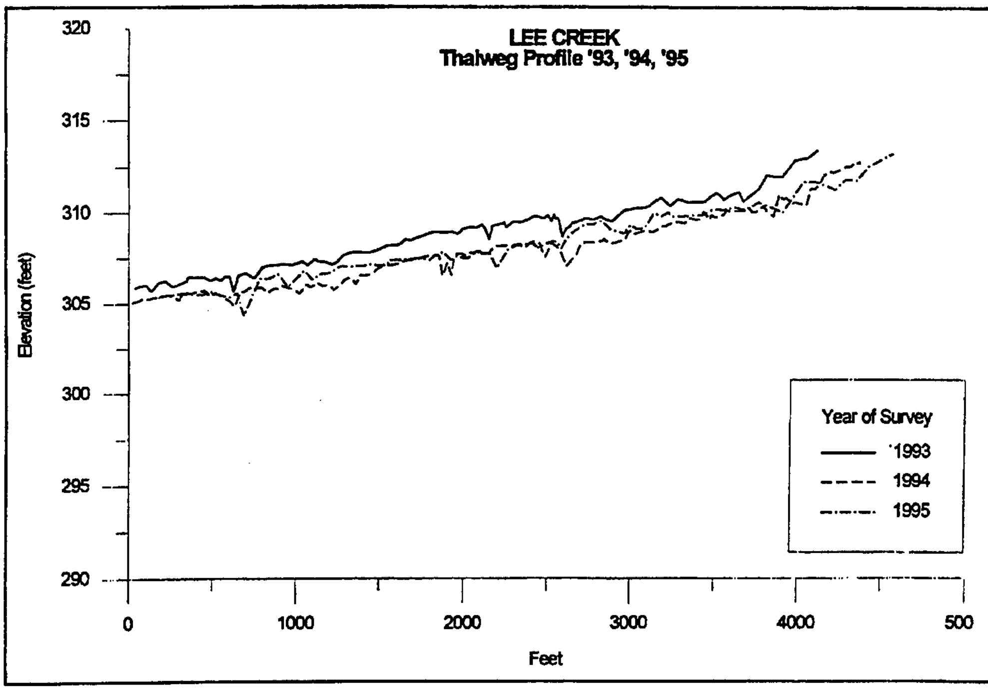


Figure 33. Thalweg profiles for Lee Creek, site #10

Lick Creek, Site 8

Site No. 8 is on Lick Creek in the Coldwater River basin, approximately 2 miles south of Olive Branch, Mississippi. Construction of a high-drop structure was started in late 1994 to protect the Highway 305 bridge. As shown in Figure 34, the study reach is approximately 4,000 feet in length, 2,000 feet upstream and downstream of the bridge, in T2S, R6W, Section 3. This site is on the Hernando quadrangle map and has a watershed area of approximately 8.5 square miles. See Table 15 for summary results and Figure 35 for thalweg profiles.

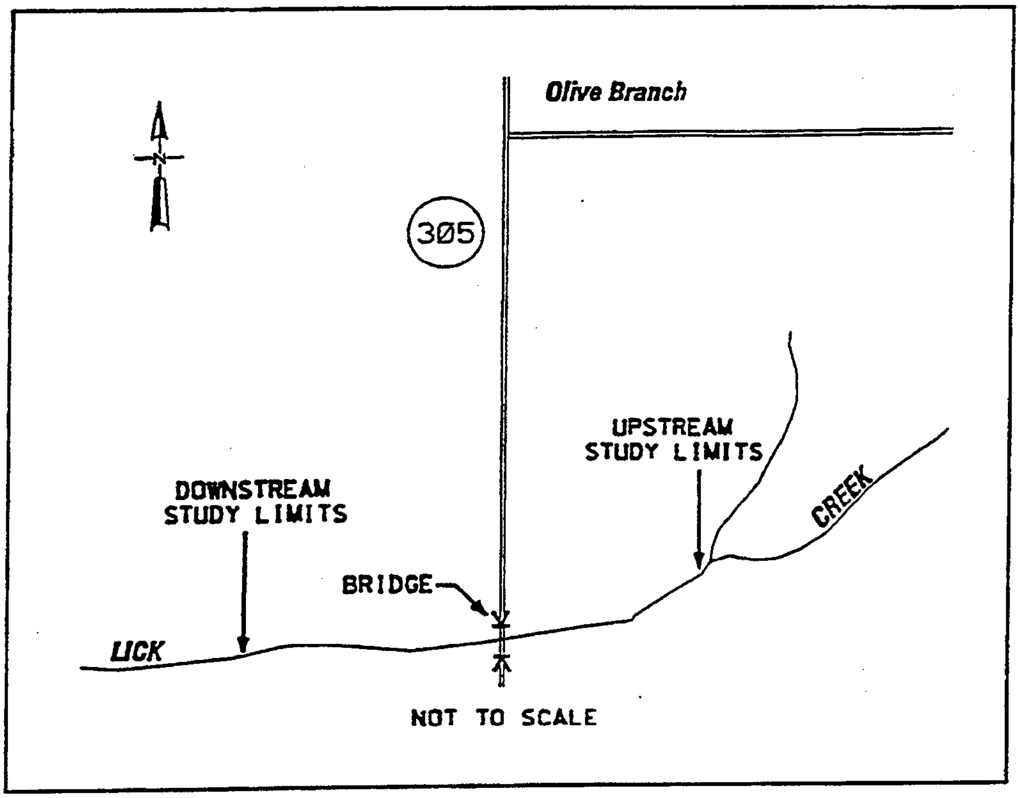


Figure 34. Lick Creek, site #8

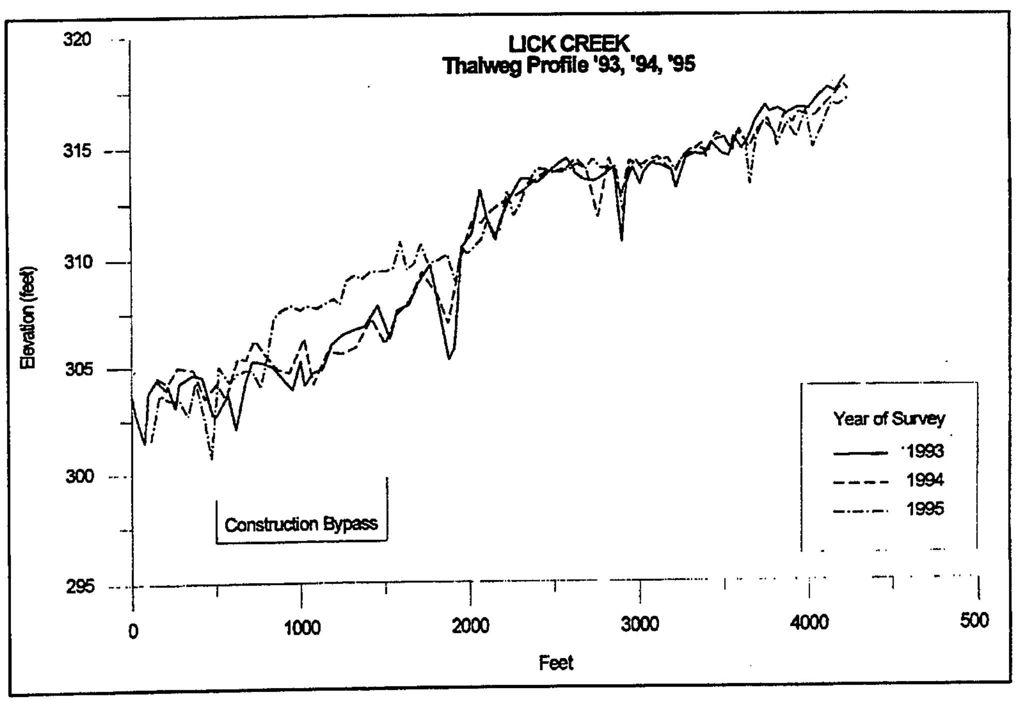


Figure 35. Thalweg profiles for Lick Creek, site #8

A high-drop structure was under construction at the time of the November, 1994 field inspection, and is located at approximate station 18+00 of the accompanying thalweg profile, Figure 35. The construction was not complete at the time of the January, 1995 survey, and the survey was made through the construction bypass as indicated in the figure. As shown on the thalweg profile, the riprap placed at the bridge (Station 20+00) as a temporary measure has helped to slow the incision that is continuing upstream and downstream of the bridge. Degradation is continuing downstream of the structure and can be expected to continue after the closure of the structure. The backwater of the structure should assist in halting the upstream incision if the knick zones have not progress too far upstream to be affected by the high drop. The high drop will protect the highway bridge. In general, the Lick Creek site is a CEM type 3 downstream and through the bridge, is a type 2 at the upper extent of the site. Presently, the upstream extent of the site is incising into resistant clay (Table 15).

The SAM analysis indicates that the slope width has been increasing. BURBANK analyses indicates that three feet of additional degradation will destabilize 50% of the Segment 1 surveyed banks and 12% of the Segment 2 surveyed banks with the assumption of zero friction angle. Left bank drainage upstream of the bridge is poor, with standing water in the adjacent field. Channel incision and a saturated left bank may combine to result in greater instability than in other similar streams. A drop pipe could be added to improve bank drainage. The high drop structure will improve the stability of the upstream channel reach, and it will be of interest to observe the upstream and downstream channel response following construction completion (Table 15).

Long Creek, Site 20

Site No. 20 is located on Long Creek, T10S, R6W, Sections 4, 5, and 8 as shown on Figure 36. The site can be found on the Oakland quadrangle map and has a watershed area of about 11 square miles. Three low-drop structures were existing prior to 1991 and the fourth was constructed in 1993 at the downstream limit of the monitoring reach. A fifth structure was constructed in 1993 downstream of the reach. The study reach is approximately 2 miles in length, extending downstream from the eastern boundary of Section 4. The site also includes a reach that has been monitored by the Vicksburg District and includes the bank stability sites reported by Thorne et al., 1990. Portions of the reach are very unstable and are presently incising. The reach downstream of the existing structures has a clay bed that was slowly incising prior to 1993. This clay bed was a very narrow, deeply incised channel along some reaches and has begun filling, a result of the new downstream structure. See Table 16 for summary results and Figure 37 for thalweg profiles.

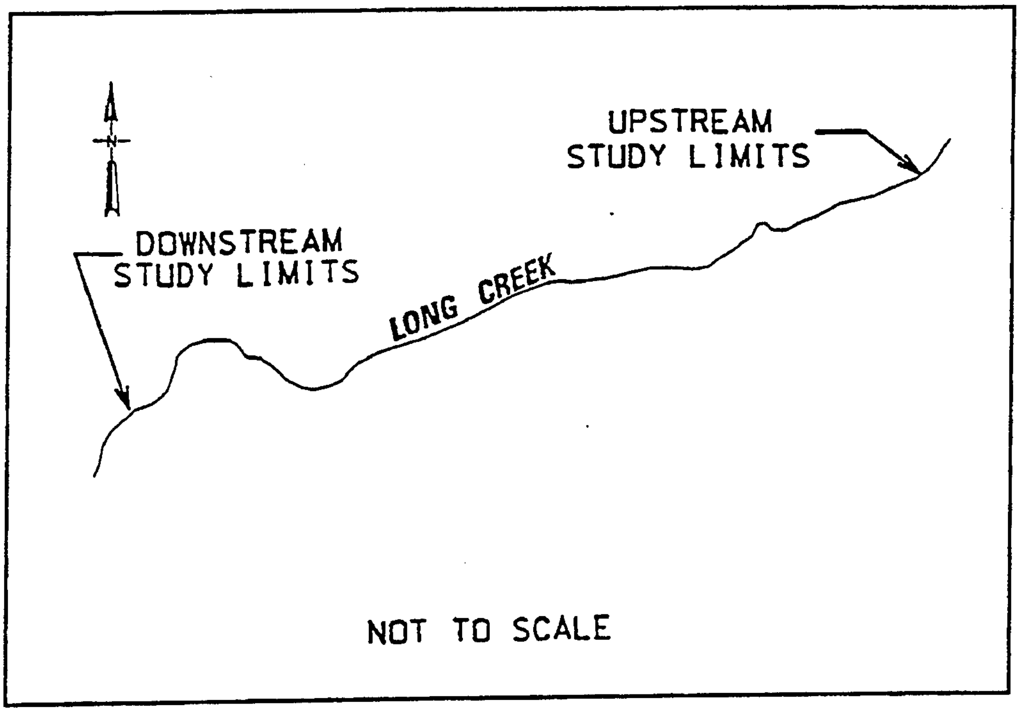


Figure 36. Long Creek, site #20

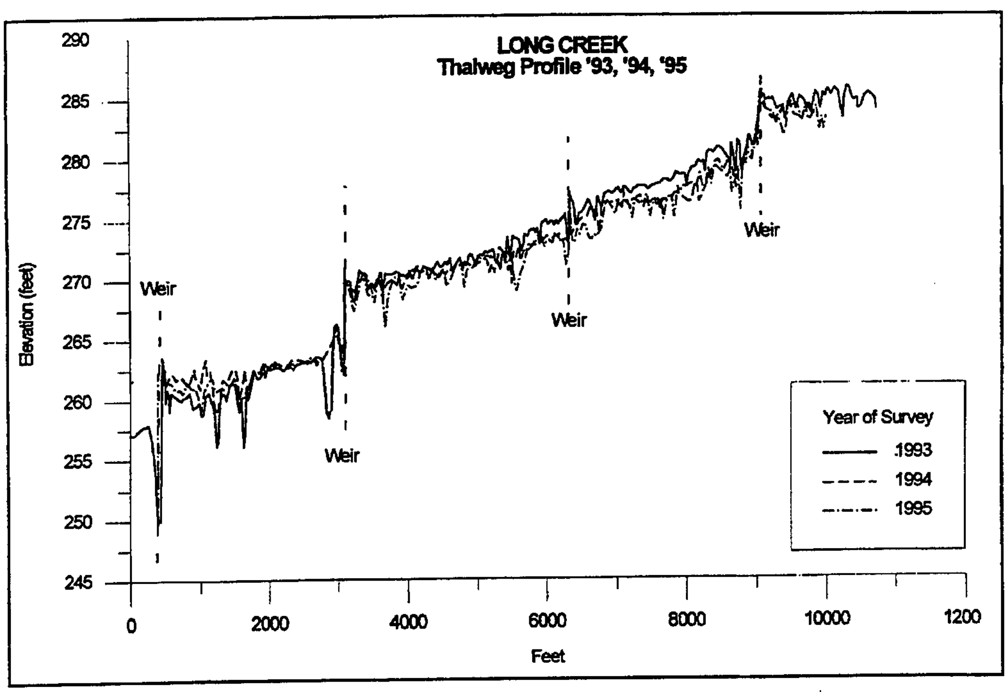


Figure 37. Thalweg profiles for Long Creek, site #20

Long Creek is divided into four segments: at station 0+00 at the fourth downstream drop structure; at approximate station 32+00 at the older low drop structure; at approximate station 68+00 at the next upstream low drop structure; and at approximate station 90+00 at the upstream weir. Figure 37 shows a thalweg profile of Long Creek. Segment 1 aggradation occurred in the period form completion of the lower drop in 1993 through the 1994 survey, and minor degradation occurred in 1994. Significant thalweg change is within 300 feet downstream of the upper weir. At this location, headcutting is moving into the weir. Numerous beaver dams that are present in segments 2, 3, and 4.

BURBANK analyses shows the significant improvement in bank stability moving upstream from Segment 1 at 33% to 0% in Segment 4. Without structural control, degradation would be continuing and the effects of 3 feet of degradation indicated in the tabulation are from 100% in Segment 1 to 6% in segment 4, which demonstrates one of the positive aspects of low drop grade control (Table 16).

Monitoring of the longterm slope adjustment of the site will furnish unique information pertaining to channel adjustment in a channel that is limited in width adjustment. From an operational viewpoint, degradation is moving up to the upstream weir and should be monitored for the safety of the structure. The upstream weir is not a low drop structure; it is an at-grade sheet pile and concrete cap with no stilling basin.

Nolehoe Creek, Site 7

Site No. 7 is located on Nolehoe Creek in the Coldwater River basin near the community of Olive Branch, Mississippi. The site is located on the Hernando quadrangle map, T1S, R7W, Section 35 and has a drainage area of approximately 3.7 square miles. The study reach is approximately 4,000 feet in length, extending downstream from a box culvert, as shown in Figure 38. The channel is extremely unstable and is deeply incised. Bed material load ranges in size from fine sand to gravel with a mean diameter in excess of 30 mm. Two low-drop structures were planned for the reach; however, permission to construct the structures was not been received from the landowner. Stream stage recording stations have been installed by WES at the downstream roadway culvert. See Table 17 for summary results and Figure 39 for thalweg profiles.

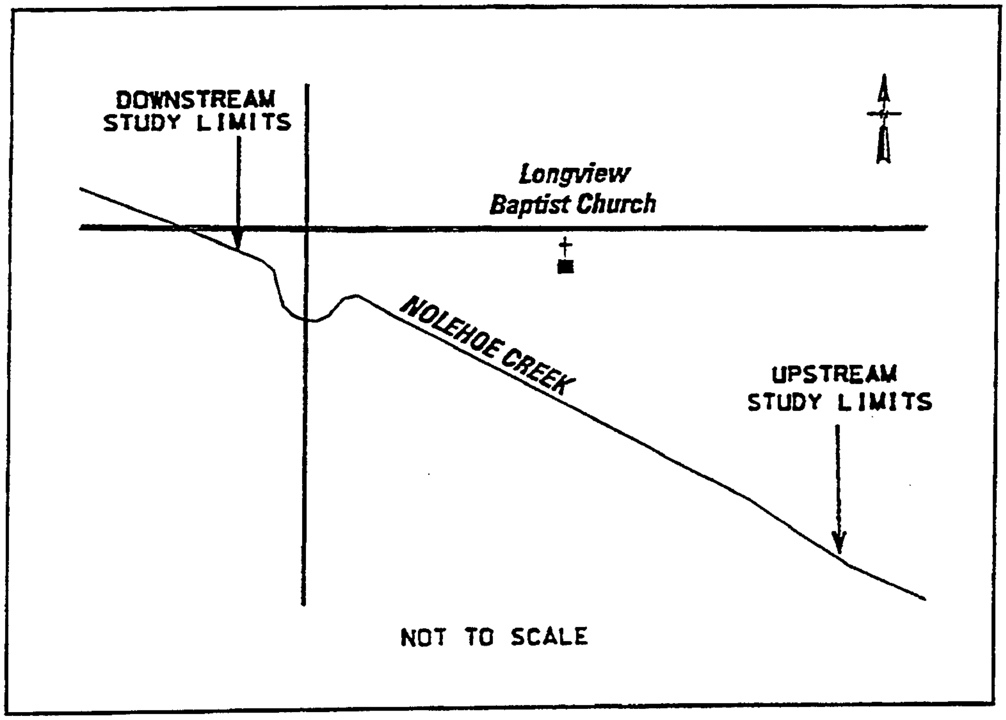


Figure 38. Nolehoe Creek, site #7

This incising reach is between upstream and downstream box culverts and the reach is representative of suburban development which is occurring in the metro-Memphis area. An interview with a local landowner confirmed that a major cutoff of the channel had been made in the last ten years. These conditions are typical of the result of ill-planned local development improvements, and the documentation of the resulting problems may be of value in assisting future local drainage planning.

The thalweg profile indicates that the lower Segment 1 has aggraded slightly and that the upper portion of the segment has changed little (Figure 39). Segment 1 has been classified as CEM 4, Segment 2 is classified as CEM 2. Segment 2, upstream of the break in slope, is very steep and dynamic. Segment 2 concentration is more than 4 time Segment 1, and continuing urbanization will accelerate the upstream degradation, which will place the upstream box culverts at risk. Channelization of Segment 2 to include grade control, and similar treatment for the tributary entering from the north a the break in slope should be considered. Property owner permission may be a major impediment to any future work.

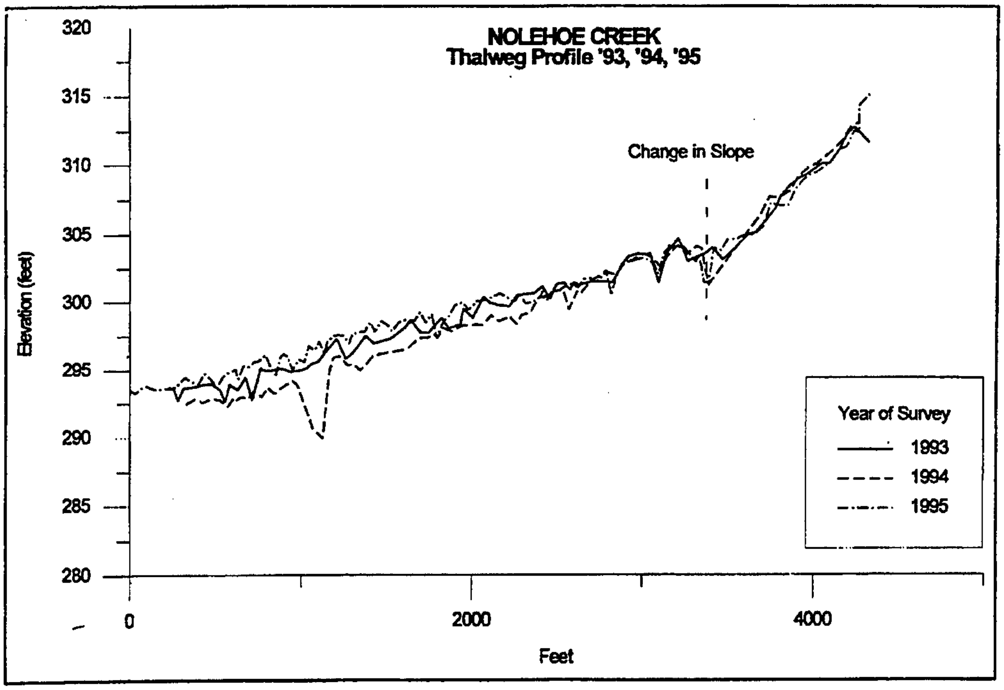


Figure 39. Thalweg profiles for Nolehoe Creek, site #7

Otoucalofa Creek, Site 14

Site No. 14 is on Otoucalofa Creek, east of Water Valley, Mississippi. The study reach is 4,000 feet in length, 2,000 feet upstream and downstream of the Mt. Liberty Church Road bridge, in T11S, R3W, Sections 4 and 5, of the Water Valley quadrangle map as shown in Figure 40. The watershed area at the site is approximately 41 square miles. See Table 18 for summary results and Figure 41 for thalweg profiles.

Presently, only riprap dikes and longitudinal dikes are constructed throughout the reach. The reach was observed to be actively incising in 1994 and this incision is occurring at an elevation below the recently placed stone. This site provided a unique opportunity to observe the riprap subjected to severe degradation, and some of the stone placed in the upstream Segment 2 has launched and was no longer visible during the November, 1995 inspection.

BURBANK results indicate that the banks are stable, and SAM results are generally consistent with the CEM 3 designation given.

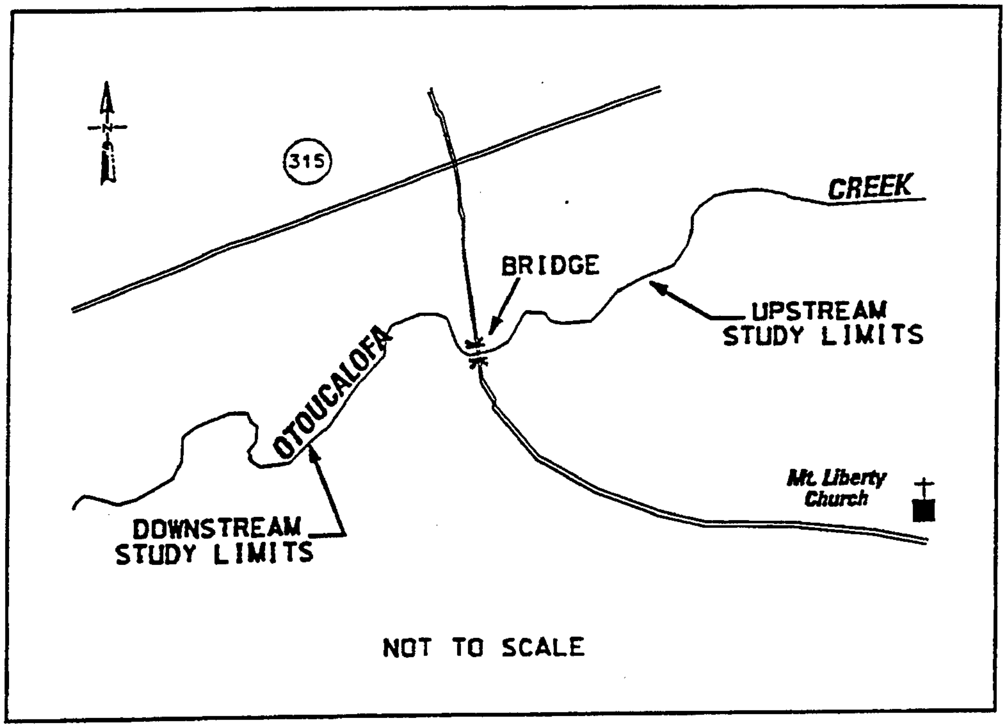


Figure 40. Otoucalofa Creek, site #14

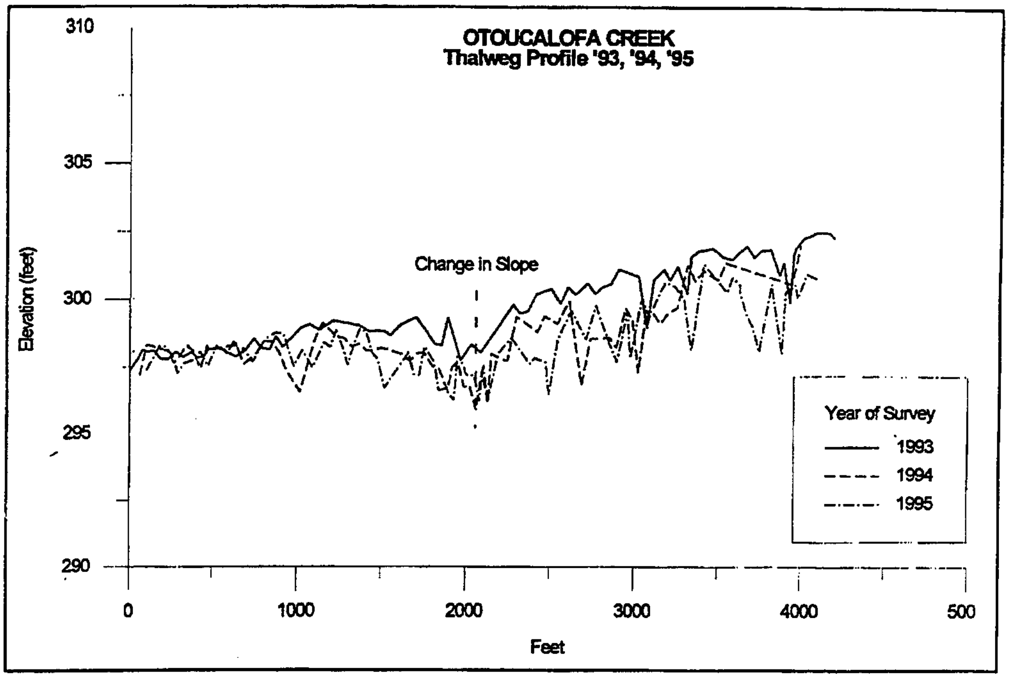


Figure 41. Thalweg profiles for Otoucalofa Creek, site #14

Perry Creek, Site 16

Site No. 16 is located on Perry Creek as shown in Figure 42. The study reach begins approximately at the T21N, R4E, Section 1 northern line and continues upstream through Sections 2 and 11. The study reach is located on the McCarley quadrangle map. The entire study reach length is approximately 2 miles, as shown in Figure 3.#. Four low-drop structures were completed during 1994. This site will allow the investigation of the effects of four structures in series. Prior to construction the site was unique because within the study reach, the channel moved from a deeply incised stream at the downstream end to a stream that might have existed prior to channelization at the upstream end. See Table 18 for summary results and Figure 43 for thalweg profiles.

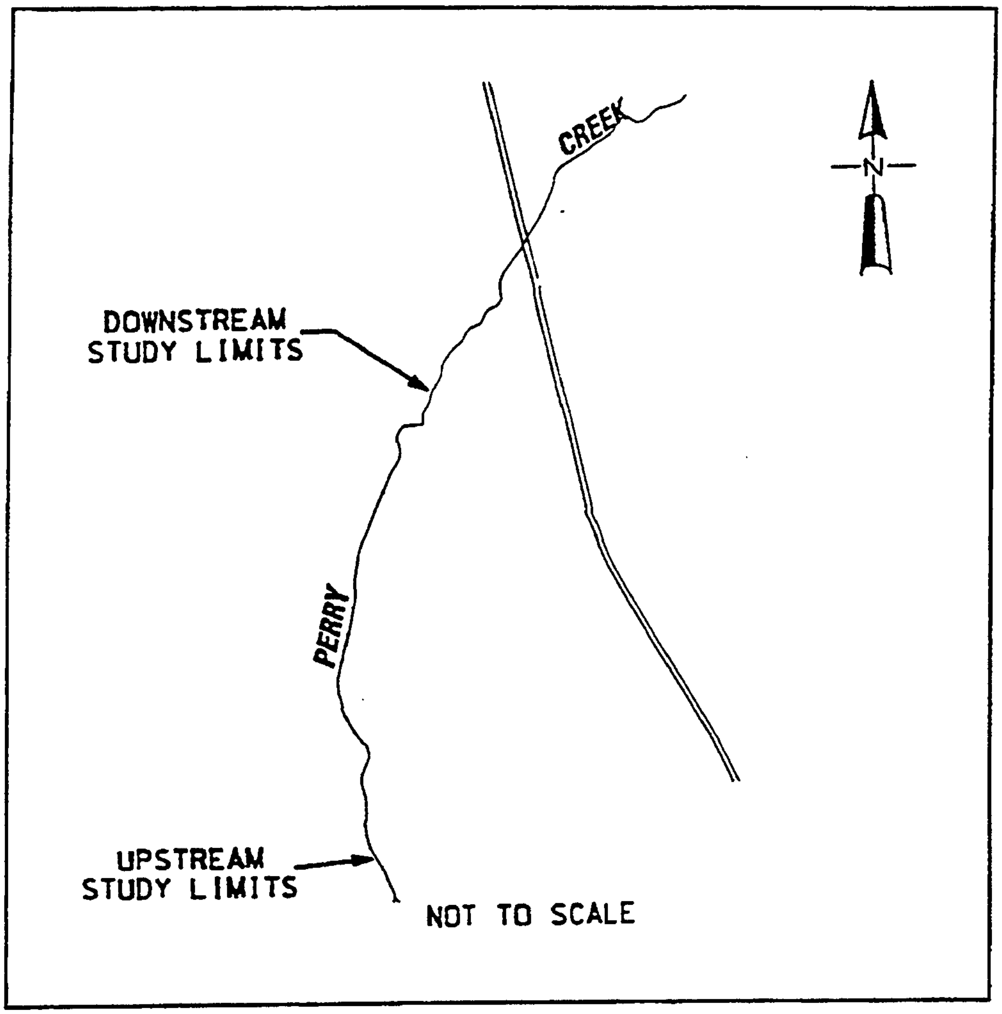


Figure 42. Perry Creek, site #16

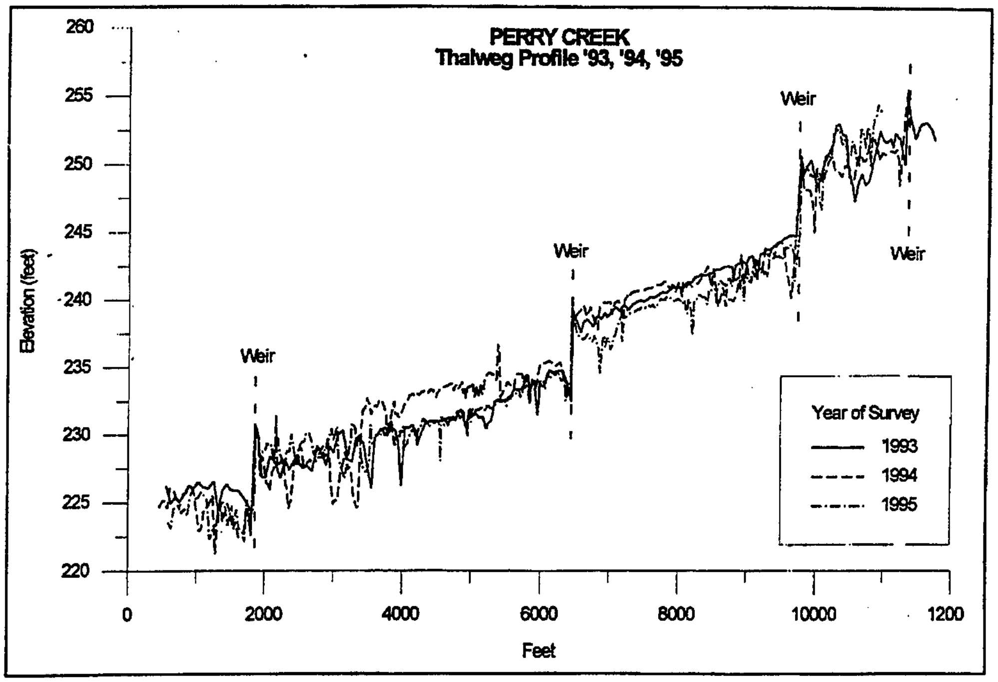


Figure 43. Thalweg profiles for Perry Creek, site #16

Downstream of the lower grade control structure, Segment 1, is ponder as a result of a downstream shale outcrop. The extent and durability of the shale is unknown, and failure of the existing headcut will result in 2 to 3 feet of degradation moving into the structure (Perry #3). Upstream of this structure, the channel is ponder. Segments 1 and 2 transport less than 1000 mg/l. Segment 3 is responding to the structure (Perry #4)and some incision is continuing upstream. A gully on the left bank approximately 500 feet downstream of Perry #5 should be considered for a drop pipe. Although the slope in Segment 4 is very steep, the bed is relatively erosion resistant ironstone and may respond slowly.

For the zero friction angle, channel bank at risk decreases from 100% in Segment 1 to 13% in Segment 4, primarily due to the decrease in bank height as structures were emplaced. The structures appear to be functioning well, and the reach should continue to stabilize as the lower reaches fill and Segment 3 flattens the slope. The stability of Segment 4 depends on the unknown bed material stability.

Redbanks Creek, Site 9

Site No. 9 is located on Red Banks Creek in the Coldwater River basin. As shown on Figure 44, the study reach extends approximately 2.5 miles upstream from the bridge on the county road between the communities of Warsaw and Watson, Mississippi. This site can be located on the Byhalia quadrangle map, T3S, R5W, Section 24, and R4W, Section 19 and 20, and has a watershed area of approximately

28 square miles. The bed sediment load is sand, and the stream flows in a deeply incised and widened, straight channel which is the consequence of earlier channelization. Sediment transport capacity of the reach averages 2700 mg/l. See Table 19 for summary results and Figure 45 for thalweg profiles.

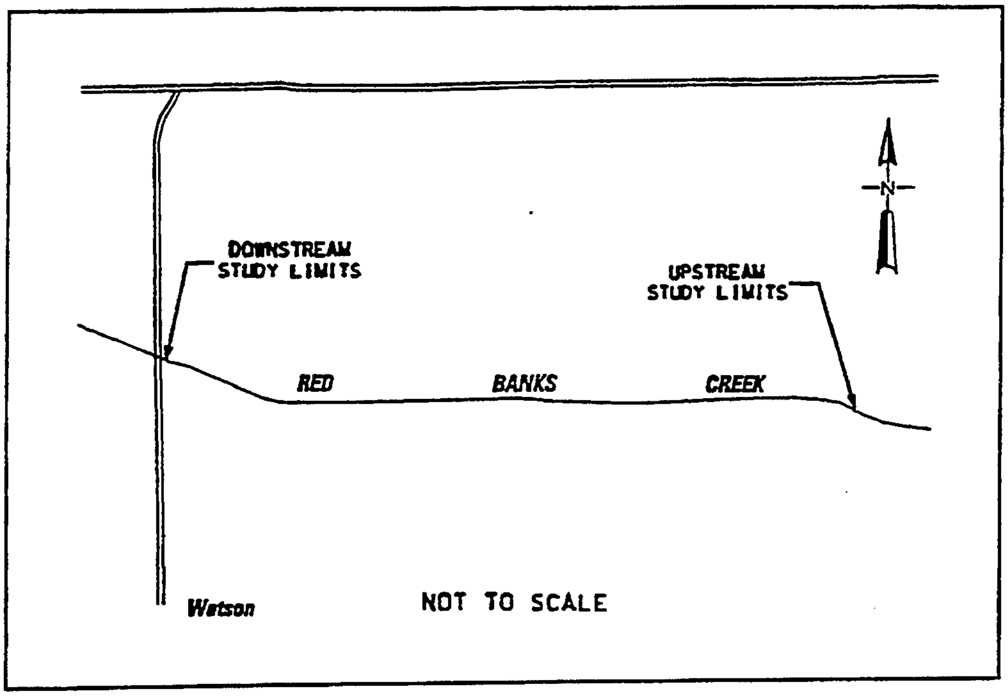


Figure 44. Redbanks Creek, site #9

Site No. 9 includes four Chevron dikes and longitudinal riprap for channel stabilization. Bank stabilization, at times along both banks, and grade control have combined to reduce bank erosion; however, the reach is generally unstable with little evidence of berm formation or developing riparian vegetation associated with a naturally stabilizing channel. No CEM designation has been given to this reach.

Bank stability increases in the upstream direction. Using the zero friction angle assumption, 100% of the banks are at risk at the downstream Segment 1 and only 8% of the banks are unstable in Segment 5. This improvement in stability is consistent with the use of serial grade control structures to reduce bank height. Consideration should be given to refurbishing the existing Chevron weirs, perhaps by rebuilding and extending the structure length. Consideration should be given to additional structures downstream. The BURBANK results indicate that the existing weirs are important in maintaining bank stability.

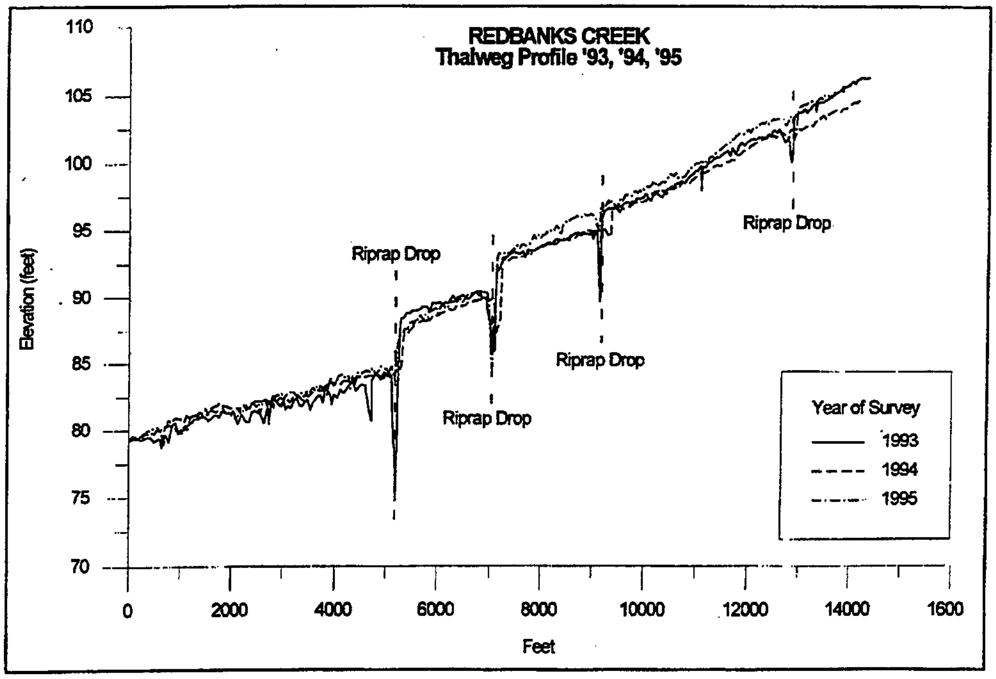


Figure 45. Thalweg profiles for Redbanks Creek, site #9

Sarter Creek, Site 15

Site No. 15 is on Starter Creek, which is a tributary of Otoucalofa Creek upstream of Site No. 14. Starter Creek is located on the Paris quadrangle map and has a watershed area of approximately 6.4 square miles. The study reach is 4,000 feet in length and is almost completely straight as a result of previous channelization, as shown in Figure 46. This site extends downstream of the Highway 315 bridge. The site is unusual in that it has remained relatively unchanged since channelization; however, it is apparent that headcutting affected the reach in 1993 and continued to degrade the bed in 1994. See Table 20 for summary results and Figure 47 for thalweg profiles.

The 1995 profile indicates continuing incision. Field inspection in November, 1995 confirmed several headcuts, and that numerous beaver dams are playing an important role in maintaining the stability of the channel. The channel ranges from a CEM 4 at the downstream extent to CEM 2 upstream, and has been given a CEM 3 designation overall. Riprap grade control should be considered for the site.

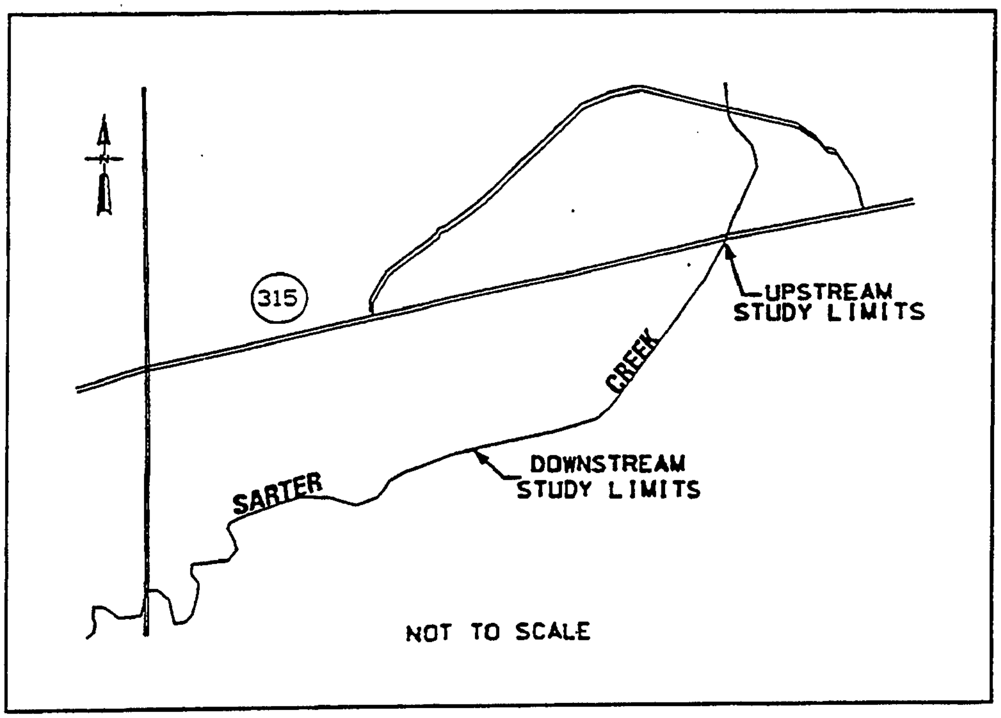


Figure 46. Sarter Creek, site #15

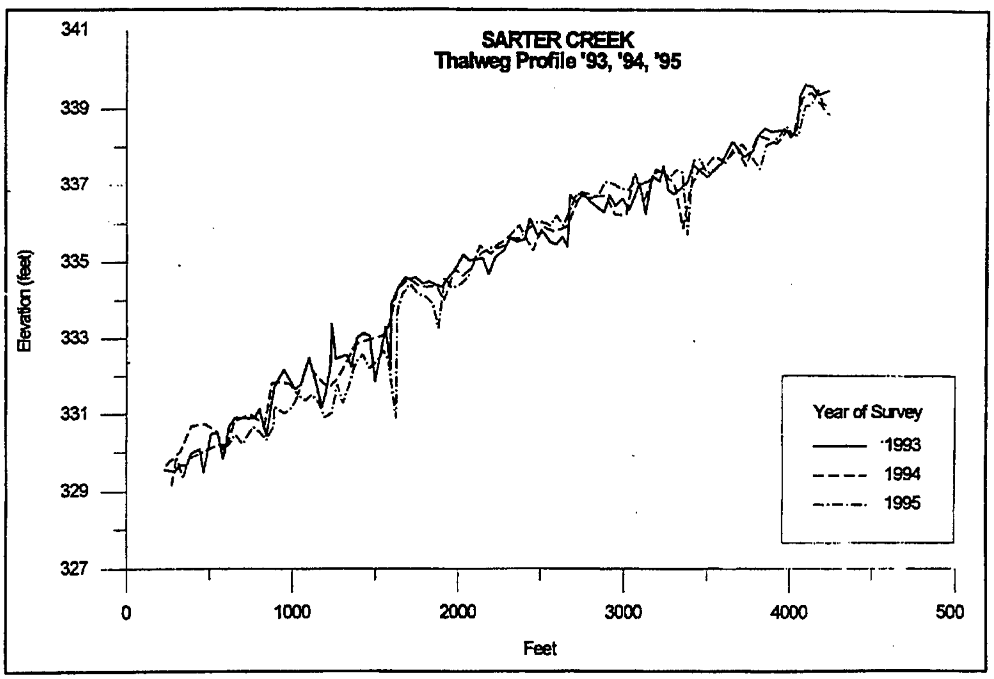


Figure 47. Thalweg profiles for Sarter Creek, site #15

Sykes Creek, Site 17

Site No. 17 is located on Sykes Creek as shown in Figure 48. The study reach extends 2,000 feet upstream and downstream of the county road bridge across Sykes Creek located in T21N, R5E, Section 27. This site is found on the McCarley quadrangle map. Gauging had been available for the approximate 12.3 square mile watershed area at the county road bridge, however, construction of a new county bridge was in progress in November, 1995 and no gauging instrumentation was in place. See Table 21 for summary results and Figure 49 for thalweg profiles.

The accompanying thalweg profile, shown in Figure 49, indicates that little change has occurred during the three year period, and by many indicators such as berm formation, depth of sand in the bed, and by thalweg comparison, the channel could be considered in quasi-equilibrium. However, comparison of the existing conditions to the slope and width required at minimum stream power for transport of 1000 mg/l indicates that the reach is transporting a high sediment load. The 1995, 2-year water surface slope is 211% of the minimum slope and the width is 71% of the width at minimum slope. In addition, BURBANK analysis indicates that approximately 40% of the channel banks are unstable if degradation occurs and the zero friction angle assumption is valid.

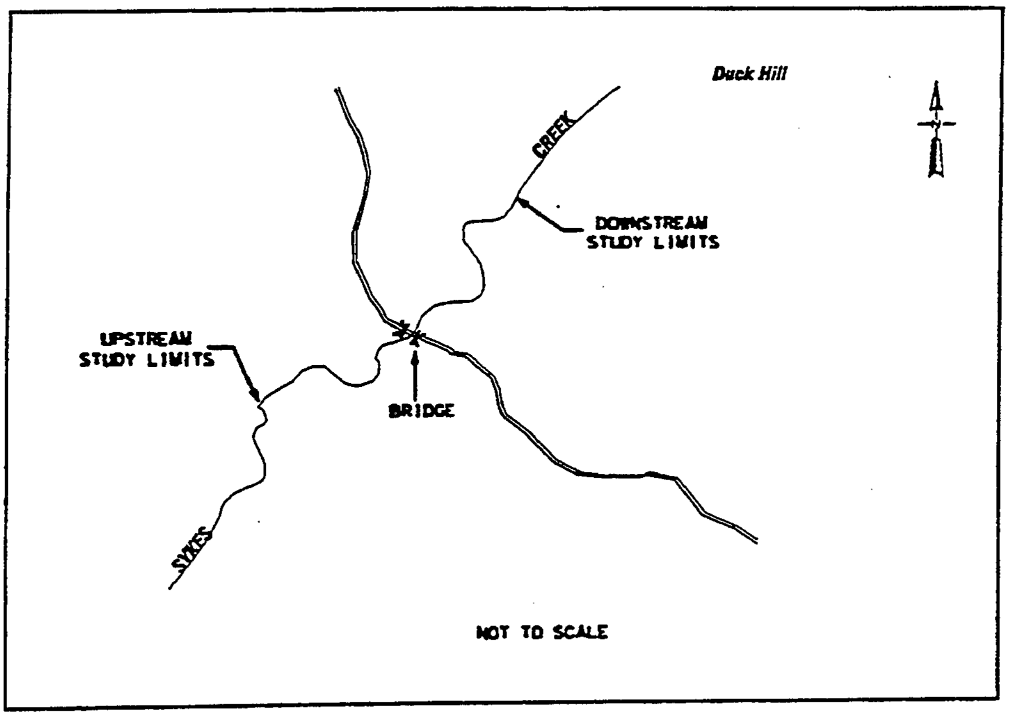


Figure 48. Sykes Creek, site # 17

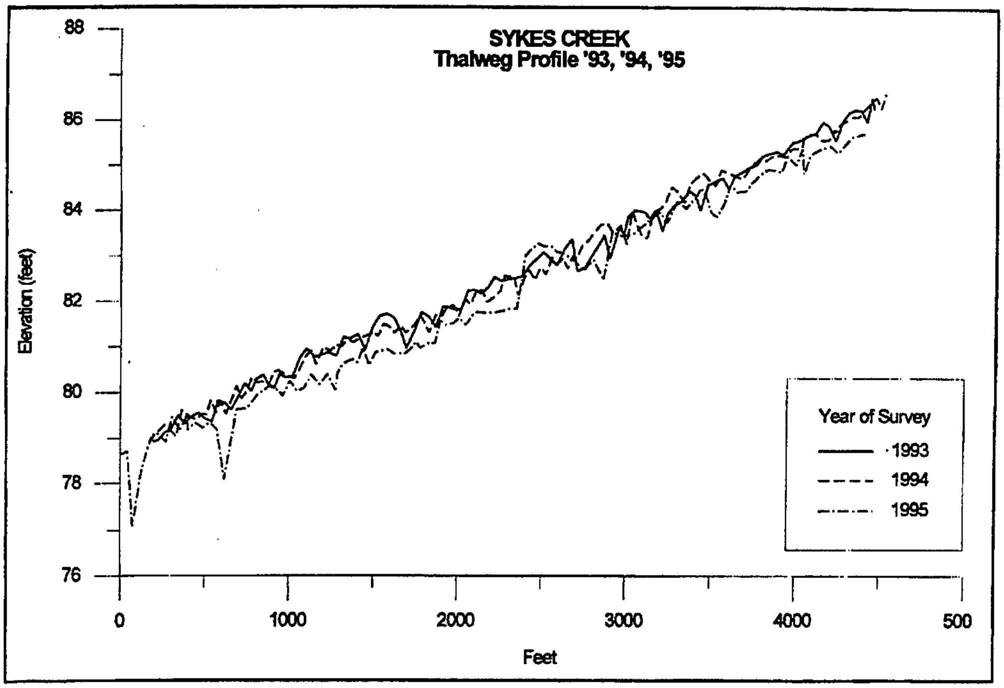


Figure 49. Thalweg profiles for Sykes Creek, site #17

About 300 feet upstream of the County bridge a large, tight bend is in the process of cutting off. Progressively during the monitoring the point bar chute has enlarged and the upstream approach has become more abrupt. During the November, 1995 inspection, a neck cutoff was forming, with most of the low flow moving beneath the neck through a tunnel approximately 2 feet in diameter. At the same time the old channel has become increasingly choked by debris. A longitudinal stone toe with tie-backs has been place to halt the migration of the upstream bend into a residential lot. After the neck cutoff is complete, the downstream following the cutoff, the downstream left bank begin to erode. The alignment to the downstream bridge is presently relatively straight, and the new alignment is uncertain. The cutoff will increase the slope locally and will cause upstream degradation.

Consideration should be given to identification of upstream sediment sources, remedial measures to reduce sediment supply, grade control, reducing the slope and the bank height, and attention to the bridge alignment.

East Worsham Creek, Site 18a

Site No. 18, comprising 18a, 18b, and 18c, is a study reach encompassing portions of Worsham Creek, East Worsham Creek, West Worsham Creek, and Middle Worsham Creek, as shown in Figure 50. The site is located on the Duck Hill quadrangle map in T20N, R6E, Sections 14, 15, 16, 21, 22, and 23. The total stream length being surveyed is approximately 3.5 miles and the watershed area at the confluence of Worsham and West Fork is approximately 19 square miles. The streams are deeply incised and active. Ten low-drop structures have been constructed in Site 18.

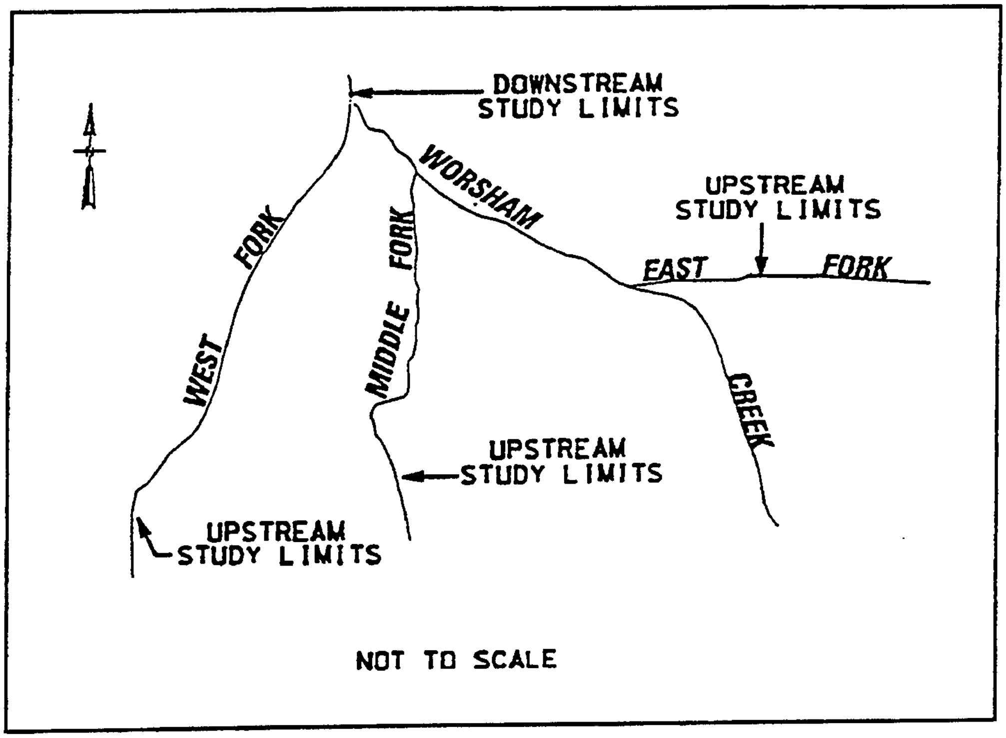


Figure 50. East Worsham Creek (Site 18a), Middle Worsham Creek (site 18b), and West Worsham Creek (Site 18c)

The downstream extent of the Site 18a, defined as East Worsham, is the confluence with Middle Worsham, which is the first confluence downstream of the highway bridge. The reach is divided into three segments. Segment 1 extends upstream from the confluence to the downstream, older structure. The short reach between the two structures is Segment 2. Segment 3 is upstream of the middle structure. The 2-year water surface slope and width as a percentage of the minimum slope and width at minimum slope for the for three segments, and the results of the BURBANK analysis are shown in the accompanying table. The thalweg profile (Figure 51) indicates the location of the structures and the variations in the profile. Downstream of Worsham No. 1 at approximately 38+00, the clay knickzone has begun to fail. In November, 1995 an inner channel was observed to have incised through the clay and to widen. With the failure of the resistant material, active headcutting will increase and will increase the stress at the upstream structure. Between Worsham No. 1 and No. 2, Segment 2 is an eroding channel with bank instability. A longitudinal stone toe along the left bank from structure to structure, with consideration of constricting the approach to No. 1, could improve bank stability and decrease the transport capacity.

Upstream of No. 2 structure, in Segment 3, the 1995 survey indicates that significant aggradation has occurred. The upper portion of Segment 3 is a hard, erosion resistant clay that has changed little in the past four years. A beneficial effect of the upstream grade control structures can be realized by comparing the BURBANK analysis of the percentage of bank at risk for the zero friction angle condition in 1995. Grade control has raised the channel bed to reduce the percentage of bank unstable from 100% in Segment 1 to 5% in Segment 3. This is a significant improvement. However, the SAM results indicate that the 2-year slope in all segments remains very high at approximately 250% of the 1000 mg/l minimum slope. See Table 22 for summary results and Figure 51 for thalweg profiles of site 18a.

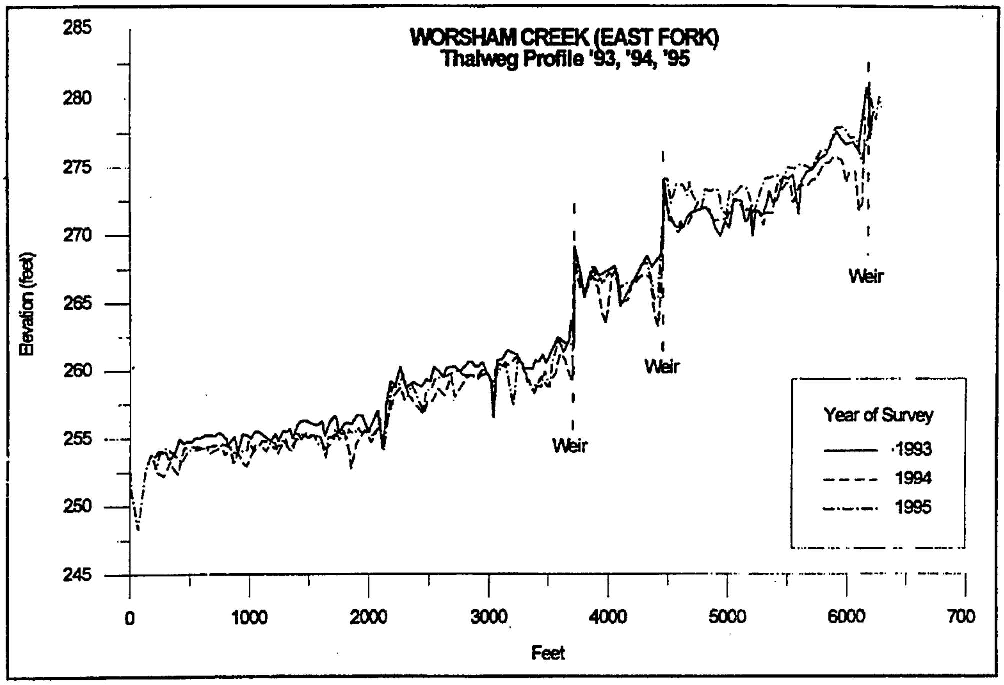


Figure 51. Thalweg Profiles for East Worsham Creek, site 18a

Middle Worsham Creek, Site 18b

The downstream extent of Middle Worsham is at the confluence with West Worsham Creek. The total reach is approximately 10,000 feet in length and is divided into four reaches by three ARS-type, low drop structures. See Table 23 for summary results and Figure 52 for thalweg profiles. The accompanying thalweg profile, Figure 52, depicts the degradation that has occurred since 1992 in the lower two segments. The primary location of degradation during the 1994-1995 period was the downstream portion of Segment 1. The table of BURBANK results clearly shows the value of the grade control structures in reducing or maintaining low bank height. Percentage of bank height unstable for the zero friction angle decreased from 67% in the lower reach to only 3% for the upstream reach. Unfortunately, in the lower reach with no grade control, the percentage of bank unstable will increase as the channel degrades. Minor degradation is continuing at the upstream extent of Segment 2, and incision was observed in the field at Segments 1 and 2. Sediment has filled to the crest of the structure in Segment 3.

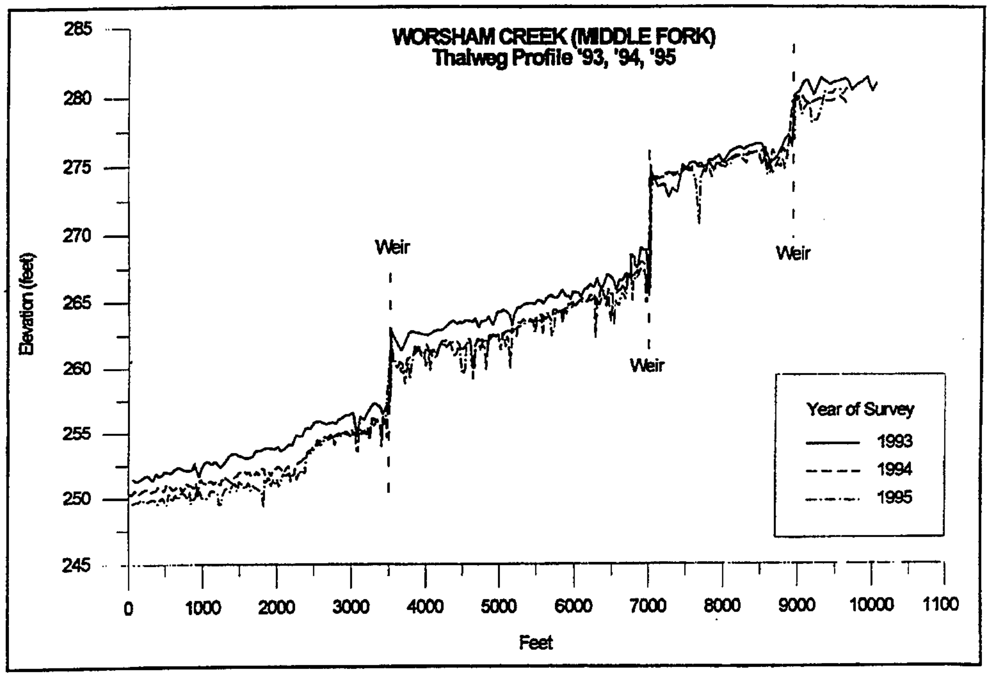


Figure 52. Thalweg profiles for Middle Worsham Creek, site 18b

Immediately upstream of the confluence of West and Middle Worsham, Segment 1 has a shallow depth of sand, less than 2 feet, for most of segment up to the confluence with East Worsham. Upstream of this confluence, the channel is narrower and nick zones are present. Two drop pipes had been cleared for surveying in 1994 and were not constructed in 1995 in this reach. Again in Segment 2, as the upstream structure is approached nick zones are present and massive bank failures are present. Headcutting in the upstream portion of Segment 3 is moving into the older structure at a slow rate, and the upstream structure basin has significant sand deposits and willow growth. Upstream of the third structure, knickpoints are present at several locations. The right bank is eroding and consideration should be given to fencing the right bank upstream of the third structure to limit cattle access. Consideration of some form of grade control should be made at the upstream extent of Segment 4.

SAM results indicate that only Segment 3 is beginning to approach stability, and has been designated CEM 4. This has been confirmed by field evidence, and may be a direct result of the constricted weir of the downstream structure.

West Worsham Creek, Site 18c

The total reach length is approximately 10,000 feet and is divided into four segments by three ARS-type low drop structures. See Table 24 for summary results and Figure 53 for thalweg profiles. The accompanying thalweg profile, Figure 53, indicates continuing degradation in the lower segment, and clearly indicates the aggradation immediately upstream of the second structure. Note that the 1995 profile indicates filling to the weir crest of the second structure, while the older, first structure has not filled. This indicates that the improved hydraulic control of the newer design results in improved performance, and suggests that renovation to improve hydraulic control is worth consideration.

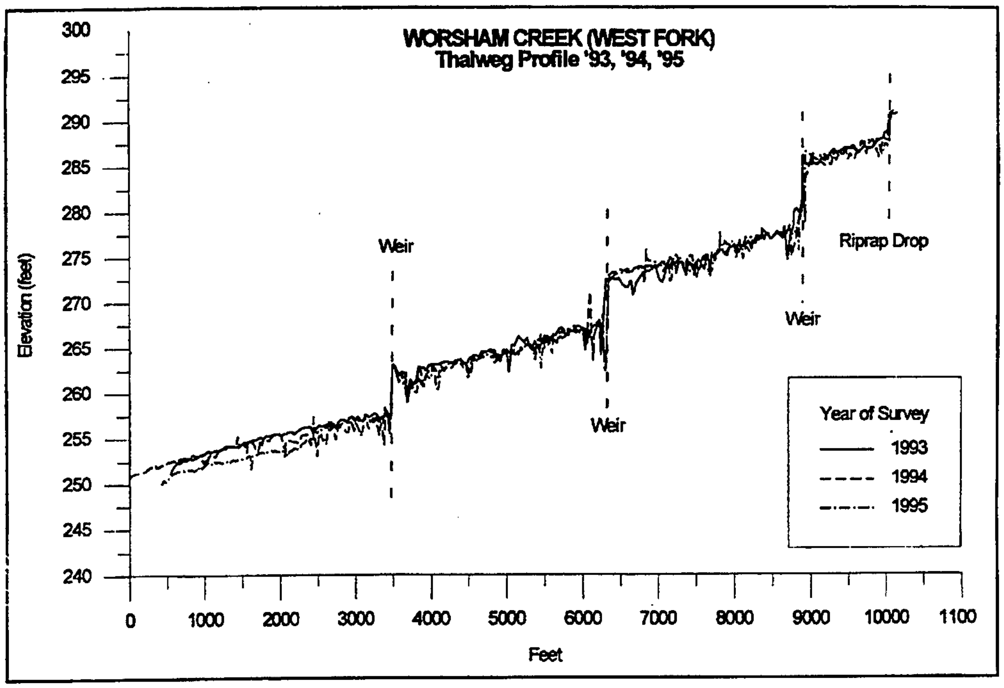


Figure 53. Thalweg profiles for West Worsham Creek, site 18c

The table of BURBANK results indicates that banks are relatively stable, except in the lower segment. This was confirmed by field inspection in November, 1995. Continued degradation will exacerbate Segment 1 bank stability. Consideration should be given to construction of grade control in the segment.

Beaver dams are abundant upstream of the second structure. The gully into the second structure has been rehabilitated. Clearing has been accomplished for work at the downstream right bank gully at that structure in 1994, however no construction occurred in 1995.

SAM results indicate that the 2-year water surface slope of the reach averages 275%, and the average stream width averages 83% of the width required at minimum stream power for transport of 1000 mg/l. Although these data indicate a relatively unstable, incising channel, significant grade control has been placed in the system. The newer, second structure has been very effective in reducing slope, from 247% to 168% of the slope at minimum stream power for transport of 1000 mg/l.

The upstream riprap grade control structure has incurred significant displacement and is still functioning. A recommendation has been made to rehabilitate this structure. Consideration should be given to adding grade control downstream of the confluence of West and Middle Worsham.

4 Analysis

An index of sediment yield that has been used previously is computed by averaging the 2-year sediment discharge for each stream, and summing the sediment yield from all streams. The following tabulation provides a comparison of the percentage sediment yield reduction from the DEC monitoring reaches.

Comparison of 2-Year Sediment Discharge

Year	Avg. 2-Year Sediment Discharge (Tons/Day)	% Reduction From 1992 Base Year
1992	345,674	-
1993	296,884	14%
1994	242,264	30%
1995	269,296	22%

The data indicate that the 1995 channel response to constructed features and natural change results in a sediment yield that is 22% less than the 1992 sediment yield. The 1995 sediment yield reduction is 8% less than the 1994 reduction. With only four years of data, it is not known if the 1994-1995 change is a minor fluctuation in the system, or a trend toward increasing sediment yield.

Review of Existing Structure Location Procedure

A critical element to providing long-term sediment yield reduction is to explicitly include sediment transport and sediment yield in the design process. The General Design Memorandum (GDM) No. 54 (1990) primarily uses a regional stability curve to design the spacing and height of grade control structures. The regional stability curve presented in Figure A-16 of that document is a relationship between thalweg slope and drainage area, and was developed by plotting the slope and drainage area

of stable channel reaches. Figure 54 depicts the original data, the regression of the original data, and data from the 1995 DEC monitoring reaches. Stability was generally defined in terms of the Channel Evolution Model (CEM) (Schumm, et al., 1984). Regression of the original data used in GDM No. 54 results in the following relationship:

$$S = 0.0041 * A^{-0.365}$$

where S is the stable slope, and A is the drainage area in square miles.

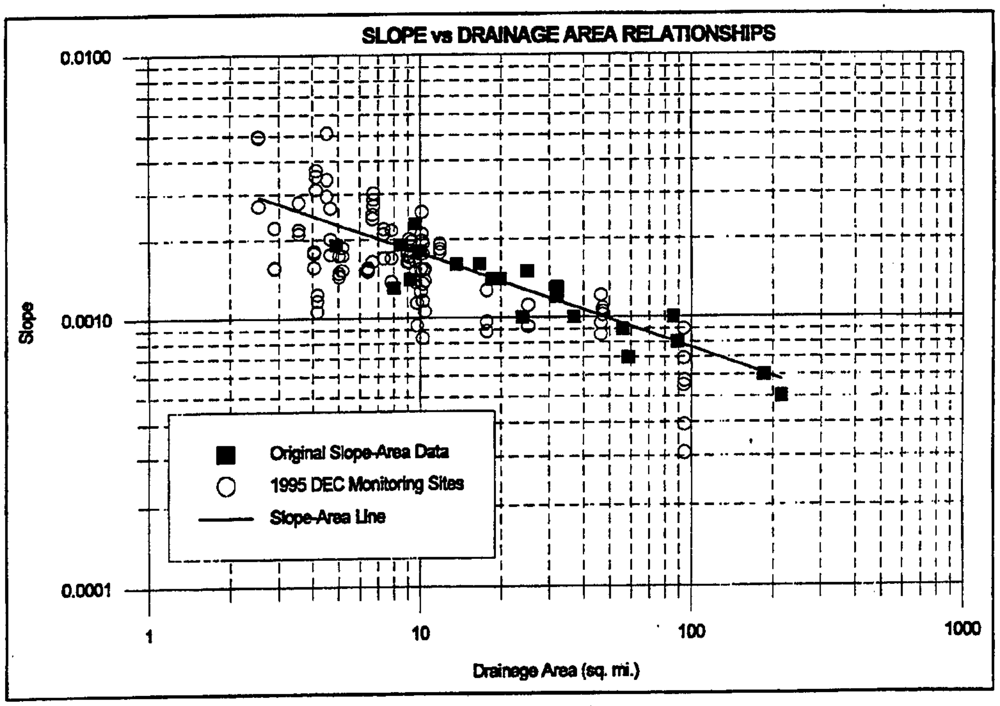


Figure 54. Slope vs drainage area relationship

One factor to consider is that drainage areas for the DEC monitoring reaches are generally smaller than the original-data drainage areas. As shown in Figure 54, only one reach less than 8 square miles was included, whereas, the DEC monitoring reaches are primarily in the range of 2 to 10 square miles. Figure 55 is a comparison of the DEC monitoring reach energy slope data shown as CEM types, and the GDM No. 54 slope-area curve. For the portion of the slope-area curve greater than 10 square miles, most of the reaches are CEM 4 or CEM 5, indicating a reasonable degree of stability. For drainage areas less than 10 square miles, the slope-area curve is defined by CEM 2 or CEM 3, generally unstable reaches. The CEM 4 less than 10 square miles in drainage area are below the relationship.

Figure 56 is similar to Figure 54, with the following exceptions: a.) 1995 DEC monitoring reach data for only CEM 4 and CEM 5 reaches are plotted; and b.) these data exclude reaches that are ponded because ponding was not included in the original conception of the CEM. A new regression was made of the plotted data and the following relationship was plotted using a solid line (Figure 56):

$$S = 0.0018*A^{-0.145}$$

using the same parameters as previously noted. The GED No. 54 relationship is shown above as the dash line. One of the primary reasons for lowering the relationship is that the sediment supply to the reaches has been reduced by the numerous drop pipes, land use improvements, and bank stabilization measures that have been emplaced by the DEC programs. Stability, as defined by the CEM criteria, includes a balance between sediment supply and sediment transport capacity. As the sediment supply has been reduced, the stable slope must also be reduced. Therefore, although the slope-area curve is a useful benchmark for comparison of reaches, the curve will require updating as success occurs in reducing sediment supply. The new relationship has a statistically poor fit; however, it demonstrates that the slope-area relationship must be re-evaluated. Consideration should be given to using design procedures that explicitly include sediment supply and transport capacity.

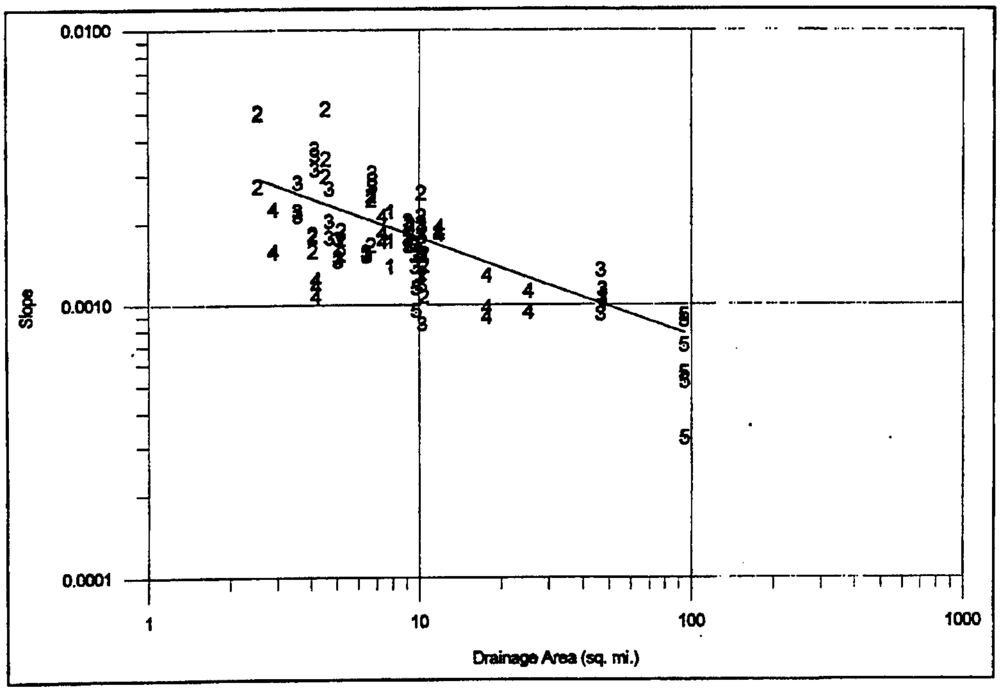


Figure 55. CEM types in comparison with a slope-area curve

Unfortunately the slope-area regional stability curve, although useful, does not explicitly include sediment yield or sediment transport capacity. The relationships only implicitly include the sediment yield of the stable channels used in the data base. Figure 57 depicts the relationship between the energy slope and the computed sediment concentration in the DEC monitoring reaches. A regression expression for the data is:

$$Concentration = 164{,}104{,}428 * S^{1.73}$$

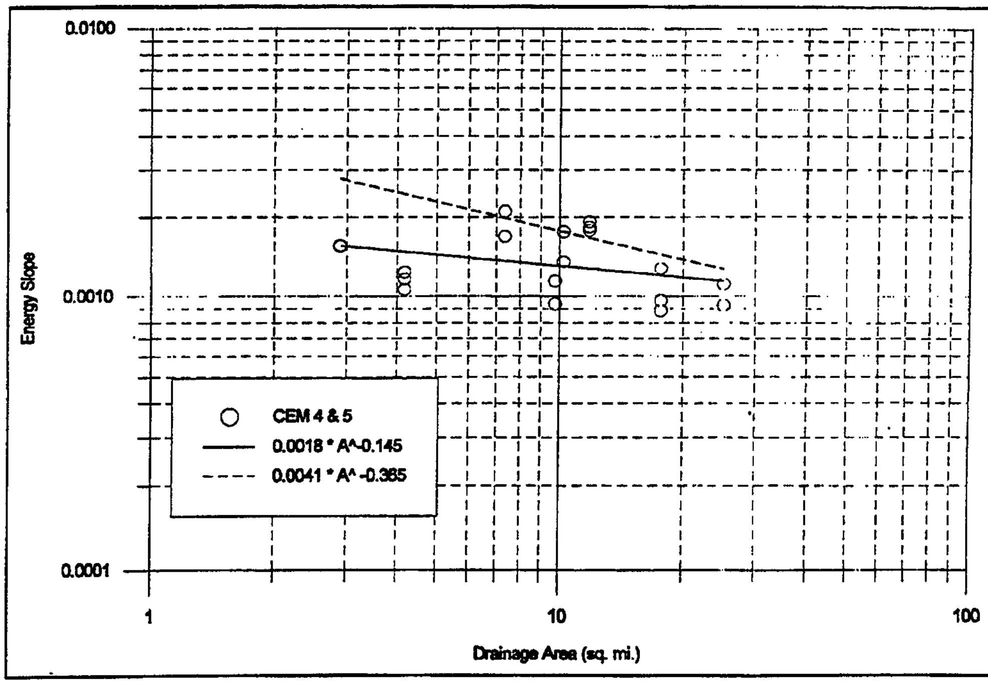


Figure 56. 1995 CEM data with two regressions

with the units of concentration as mg/l, and S is the energy slope. The coefficient of determination (R^2) is 0.89. As shown in Figure 4.4, the sediment concentration for S = 0.0009 is approximately 1000 mg/l, for S = 0.004 the concentration is approximately 10,000 mg/l. Figure 4.5 shows the slope-area curve from GDM No. 54, and has values of sediment concentration taken from Figure 4.4 for selected drainage areas. Therefore, using the slope-area curve for stable channel design would require the designer to accept 712 mg/l at 90 square miles, 2849 mg/l at 10 square miles, and extrapolating the relationship, 7170 mg/l at 2 square miles.

The consequence of designing grade control using the GDM No. 54 slope-area curve, when considered in a sediment transport frame of reference, can be examined in a general sense using data from the DEC monitoring reaches. The average sediment transport capacity expressed as a concentration for all of the DEC monitoring reaches at the 2-year discharge is 3428 mg/l. The average drainage area for the DEC monitoring reach segments with grade control is 7.4 square miles, and from Figure 4.5 the average sediment concentration is 3446 mg/l using the GDM No. 54 slope-area curve. Therefore, reaches that include grade control structures designed using the GDM No. 54 slope-area curve may reduce sediment concentration in those reaches, however, the reaches would continue to contribute sediment at the same or greater concentration as compared to the present overall average concentration. A new procedure should be considered to enable design for reduction of sediment yield.

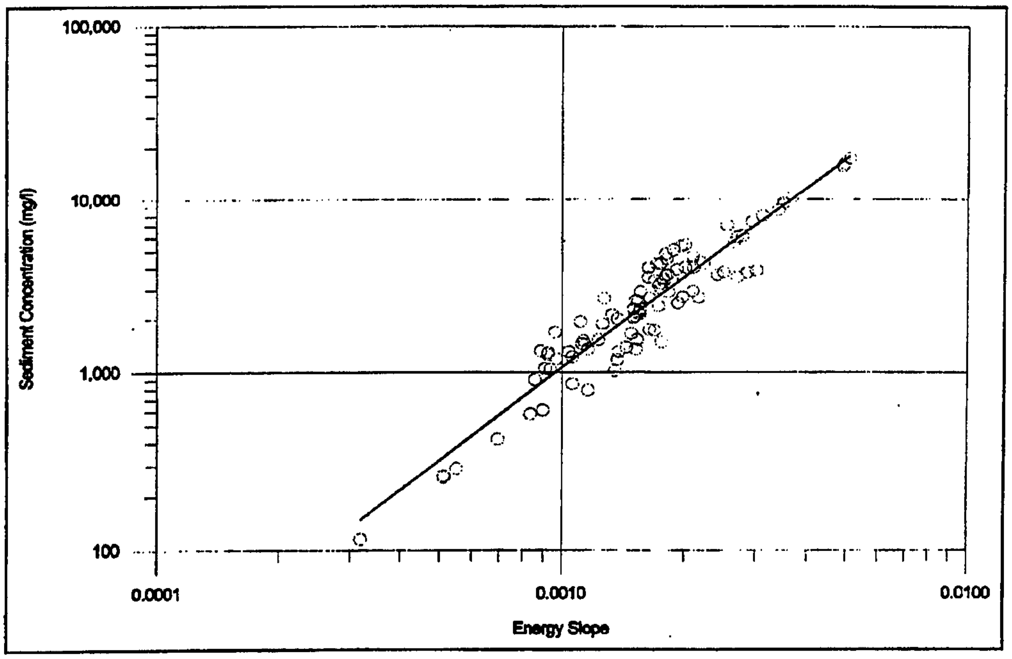


Figure 57. Relationship between energy slope and computed sediment concentration For DEC monitoring reaches

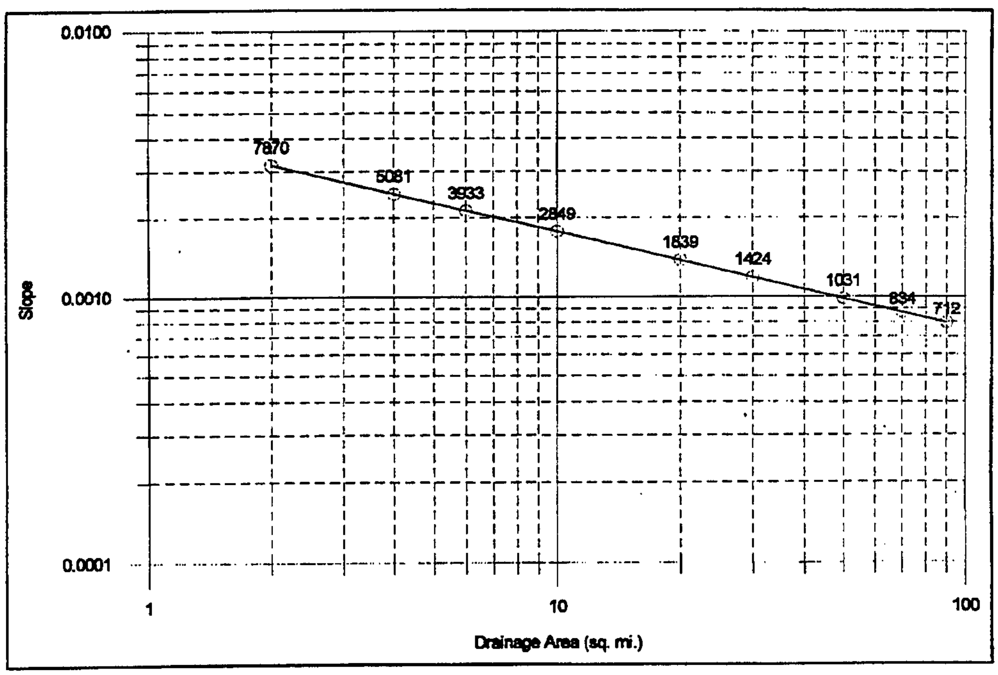
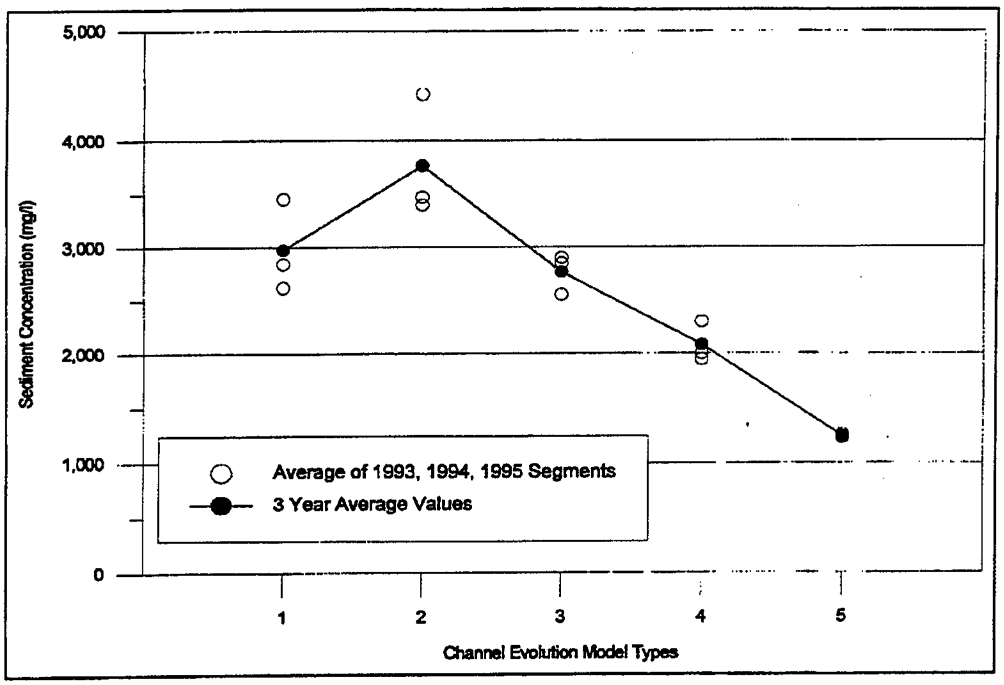


Figure 58. Sediment concentration for the 2-year discharge along the GDM No. 54 slope-area curve

Proposed Structure Location Procedure

The proposed structure location procedure would be to select an energy slope based on the desired sediment transport concentration. The sediment transport concentration of the CEM 5 reaches within the DEC monitoring reaches can be used to select a design slope. Figure 59 provides a summary of the sediment concentration for CEM types for 1993, 1994 and 1995; the line through the data is the average for each CEM type. Figure 4.4 can be used to estimate the energy slope. The data indicates the design slope for the CEM 5 concentration of 1000 mg/l would be approximately 0.001, and the CEM 4 concentration of 2000 mg/l would be 0.0014. Structures could be located using this range of bed slopes, which would reduce sediment concentration below the existing average sediment transport. A check could then be made comparing bed slope and energy slope, and adjustments could be made if required.

Figure 59. Computed sediment concentration for CEM types



Critique of Proposed Structure Location Procedure

The proposed procedure has the limitation of depending on the present field identification of CEM 4 and CEM 5 reaches. Just as with the GDM No. 54 slope-area curve, as the watersheds continue to stabilize the sediment concentrations will decrease, requiring that the sediment concentration of the CEM 4 and CEM 5 reaches be reviewed and, perhaps updated. The procedure is applicable even though CEM may not be applicable at the site.

Another approach to selecting the proper sediment supply would be approached in the following steps:

a. Assess sediment sources such as gullies, bank erosion, overbank watershed sources, and others to estimate the total watershed sediment yield on an annual basis using comparative surveyed cross sections, aerial photography, Universal Soil Loss Equation, etc.;

b. From that assessment, estimate the sediment sources that could be eliminated using drop pipes, bank stabilization, grade control, and land use management practices to determine a best-practice sediment supply for the watershed.

The sediment transport capacity of the channel reach would then be computed using the following steps:

c. Develop a sediment rating curve similar to Figure 57.

d. Generate a flow-duration curve, i.e., a relationship between the discharge and the percentage of time during the year that a particular discharge occurs;

e. Compute the annual sediment yield as the summation of products of the rating curve and the flow-duration curve;

f. Adjust either the sediment rating curve using grade control, or the flow-duration curve using reservoir detention to meet the best-practice sediment supply for the watershed.

Standard computational procedures could then be used to check steady discharge or long-term simulation of the channel response. The alternate procedure is more intensive; however, additional planning elements and solution methods could be considered.

5 Summary and Recommendations

This annual report for 1995 is the fourth in the series of DEC annual reports. Through the past four years, the DEC monitoring program has afforded the opportunity to develop an excellent data base of channel response, to extend the use of the SAM program as a monitoring and design tool, to develop the BURBANK program for monitoring of channel bank stability, and to interact with other researchers, designers, and students in their projects. The knowledge and design tools utilized in DEC streams have been applied to streams in Montana, Missouri, and Colorado, in addition to the Mississippi streams. A summary and recommendations of the monitoring programs are given in the two subsequent sections.

Summary

1. Approximately 122,000 feet of stream channel has been surveyed twice in 1995, which includes cross-section surveys in January and thalweg surveys in June. The 1995 surveys are the fourth data set for the DEC monitoring sites, and comparison of the previous data have provided a basis for establishing trends in channel response and structure performance. Comparison of the 1992 and 1995 average sediment discharge concentration indicates a reduction of 22 percent.

2. All of the data for 1993, 1994, and 1995 has been re-calculated and the results of the past three years are presented in tabular form for each stream in Chapter 3. Comparative thalweg profiles and a narrative for each stream are also presented. SAM has continued to be used as the basis for comparison of the hydraulic stability of the monitoring reaches. Comparison of the 2-year hydraulic gradient with the minimum slope channel morphology for the transport of 1000 mg/l is the baseline against which each segment is compared. SAM is also used to compute an average sediment discharge at the 2-year discharge, averaging all sites. BURBANK calculation of the bank stability is the comparison standard for bank stability. BURBANK results are reported as percentage of bank at risk of failure.

3. Review of the individual BURBANK stability calculations indicates that grade control structures are very effective in reducing bank height and reducing bank instability.
4. Two primary design goals could be the focus of stabilization design: 1) arrest

headcut migration and induce channel stability for the prevailing sediment supply; and 2) control sediment yield and induce channel stability for the desired sediment supply. Design for a new, desired sediment yield introduces an added dimension to empirical relationships such as the slope-area relationship. Prior empirical stability criteria have not included sediment discharge or sediment yield directly, and have been based on the observation of channel morphology, vegetation, and change in thalweg elevation or the water surface elevation of a specific discharge. While geomorphic stability can be implied by these observations, only an imbalance between sediment supply and sediment yield can readily be detected as instability by assessment of geomorphic stability. Quantification of sediment yield and the relationship between channel morphology and sediment discharge must be included in the design of channel stabilization measures for the control of sediment transport to downstream reaches.

Recommendations

Specific recommendations are contained in the following paragraphs.

1. Continue to develop sufficient hydrology to define reliable flow-duration relationships for any site in the DEC.

2. Concentrate efforts to assess channel hydraulic roughness data. Improve data collection accuracy if initial assessment indicates improvement is required. Consider relocation of recording gauges to develop these data.

3. The capability of SAM to predict sediment transport in gravel or mixed-bed channel should be appraised for streams such as Harland Creek and Abiaca Creek. Modification of the program is recommended to incorporate the full range of sediment size encountered in the DEC.

4. Utilize the sediment-concentration based structure location procedure presented in Chapter 4 to plan for stable channel reaches that are transporting less sediment. Re-assess existing drop structures and plan for lower sediment transport rates that will decrease overall sediment yield from the DEC basins.

5. Consider the use of lower cost, loose riprap grade control structures. Structures that increase the water surface elevation 2 feet in height have been used with success in other locations.

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Table 1
Summary Data for All Streams at 2-Year Event

			2 year	Bankfull			At lesser of two year flow or bankfull		
Site No.	Stream name	Year first Surveyed	Discharge (cfs)	Discharge (cfs)	D50 (mm)	Segment	Approx. Width (ft)	Approx. Depth (ft)	Approx. Slope
1	Harland	Jan 1992	3739	1970	.50	1	81	6.0	.000 86
2	Fannegusha	Jan 1992	3325		.31	1	82	7.8	.000 96
3	Abiaca 3	Jan 1992	3339	1700	.26	1	61	6.3	.000 92
4	Abiaca 4	Jan 1992	3780	900	.48	1	71	3.4	.001 45
5	Coila	Jan 1992	4780	730	10.24	1	80	2.8	.001 59
6	Abiaca 6	Jan 1992	7095	2020	.50	1	97	5.5	.000 69
						1	38	4.6	.002 36
7	Nolehoe	Jan 1992	978		.62 *	2	26	4.2	.006 45
						1	61	4.2	.003 01
8	Lick	Jan 1992	1580		.62	2	41	5.8	.002 41
						1	113	6.6	.001 29
						2	97	6.5	.001 80
						3	96	6.2	.002 11
						4	108	6.2	.001 69
9	Redbanks	Jan 1992	3951		.51	5	98	6.4	.001 88
10	Lee	Jan 1992	1377	900	.39	1	43	4.5	.001 56
						1	49	5.3	.001 53
11	Hickahala	Jan 1992	2158	1290	.51	2	40	5.7	.001 73
						1	103	9.0	.000 24
12	Burney Branch	Jan 1992	2662		.37	2	84	6.4	.001 14
13	Upper Hotopha	Jan 1992	1180		.31	1	75	8.0	.001 07
13	Marcum	Jan 1992	1190		.31	1	34	4.4	.004 92
						1	71	7.1	.001 84
13	Lower Hotopha	Jan 1992	3386		.31	2	71	9.1	.000 83
						1	82	9.2	.001 08
14	Otoucalofa	Jan 1992	4617		.39	2	86	9.3	.000 95
15	Sarter	Jan 1992	1391	1010	.38	1	41	5.1	.001 52
						1	114	8.2	.000 13
						2	80	6.9	.000 45
						3	49	6.2	.001 69
16	Perry	Jan 1992	1790		.33	4	49	5.2	.002 94
17	Sykes	Jan 1992	2542		.34	1	72	5.9	.001 92

Table 1 (Concluded)
Summary Table for All Streams at 2-Year Event

Site No.	Stream name	Year first Surveyed	2 year Discharge (cfs)	Bankfull Discharge (cfs)	D50 (mm)	Segment	At lesser of two year flow or bankfull: Approx. Width (ft)	Approx. Depth (ft)	Approx. Slope
						1	46	6.6	.001 80
						2	51	6.3	.001 71
18 a	East Worsham	Jan 1992	1935		.26	3	51	6.2	.001 81
						1	34	5.9	.001 56
						2	40	4.9	.002 11
						3	50	4.7	.001 55
18 b	West Fork Worsham	Jan 1992	1096		.32	4	30	4.5	.004 92
						1	43	5.1	.017 30
						2	42	5.2	.001 75
						3	51	5.4	.001 06
18 c	Middle Fork orsham	Jan 1992	1153		.29	4	36	4.8	.003 11
						1	70	6.2	.001 26
19	James Wolf	Jan 1992	2189		.36	2	73	5.6	.001 64
						1	48	4.1	.001 93
						2	69	3.7	.001 35
						3	45	4.3	.001 98
20	Long	Jan 1992	2209	960	.38	4	58	4.1	.001 37
21	Abiaca 21	Jan 1993	5750		.35	1	104	13.1	.003 09
22	Hickahala	Jan 1993				1			
23	Harland	Jun 1993	750			1	73	3.6	.000 84

Table 2
Abiaca Creek (Site #3) Summary Results

BANK MATERIAL PROPERTIES		BASIN PROPERTIES		SEDIMENT PROPERTIES	
Unit weight:	121 (lbs/ft^3)	2 year flow:	1700 (cfs)	D50:	0.25 (mm)
Cohesion:	331 (lbs/ft^2)			sigma:	1.77

1995 SEGMENT PROPERTIES

	Basin Area (mi^2)	Slope (ft/ft)	Width (ft)	Depth (ft)	Conc (mg/l)	CEM	Segment Stable	Grade Control	Bank Stab.
Segment 1	25.2	0.00092	61	6.3	1253	4	n	n	n
Segment 2									
Segment 3									
Segment 4									
Segment 5									

BURBANK RESULTS

	Bed Degradation (feet)	Friction angle: 0 1993	1994	1995	Friction angle: 14.7 1993	1994	1995
Segment 1	0	6	6	6	0	0	0
	1	12	6	6	0	0	0
	2	19	12	12	0	0	0
	3	19	19	12	0	0	0
Segment 2	0						
	1						
	2						
	3						
Segment 3	0						
	1						
	2						
	3						
Segment 4	0						
	1						
	2						
	3						
Segment 5	0						
	1						
	2						
	3						

SAM RESULTS

	Slope as percent of min slope 1993	1994	1995	Width as percent of width at min slope 1993	1994	1995
Segment 1	115	141	116	91	88	92
Segment 2						
Segment 3						
Segment 4						
Segment 5						

Table 3
Abiaca Creek (Site #4) Summary Results

BANK MATERIAL PROPERTIES			BASIN PROPERTIES		SEDIMENT PROPERTIES	
Unit weight:	121	(lbs/ft^3)	2 year flow:	900 (cfs)	D50:	0.49 (mm)
Cohesion:	331	(lbs/ft^2)			sigma:	4.71

1995 SEGMENT PROPERTIES

	Basin Area (mi^2)	Slope (ft/ft)	Width (ft)	Depth (ft)	Conc (mg/l)	CEM	Segment Stable	Grade Control	Bank Stab.
Segment 1	42.4	0.00145	71	3.4	850	0	y	n	n
Segment 2									
Segment 3									
Segment 4									
Segment 5									

BURBANK RESULTS

	Bed Degradation (feet)	Friction angle: 0 1993	1994	1995	Friction angle: 14.7 1993	1994	1995
Segment 1	0	6	0	0	0	0	0
	1	6	0	0	0	0	0
	2	6	0	0	6	0	0
	3	19	0	0	6	0	0
Segment 2	0						
	1						
	2						
	3						
Segment 3	0						
	1						
	2						
	3						
Segment 4	0						
	1						
	2						
	3						
Segment 5	0						
	1						
	2						
	3						

SAM RESULTS

	Slope as percent of min slope 1993	1994	1995	Width as percent of width at min slope 1993	1994	1995
Segment 1	82	71	87	150	127	148
Segment 2						
Segment 3						
Segment 4						
Segment 5						

Table 4
Abiaca Creek (site #6) Summary Results

BANK MATERIAL PROPERTIES
Unit weight: 121 (lbs/ft^3)
Cohesion: 331 (lbs/ft^2)

BASIN PROPERTIES
2 year flow: 2020 (cfs)

SEDIMENT PROPERTIES
D50: 0.37 (mm)
sigma: 1.90

1995 SEGMENT PROPERTIES

	Basin Area (mi^2)	Slope (ft/ft)	Width (ft)	Depth (ft)	Conc (mg/l)	CEM	Segment Stable	Grade Control	Bank Stab.
Segment 1	93.9	0.00069	97	5.5	422	5	y	n	n
Segment 2									
Segment 3									
Segment 4									
Segment 5									

BURBANK RESULTS

	Bed Degradation (feet)	Friction angle: 0 1993	1994	1995	Friction angle: 14.7 1993	1994	1995
Segment 1	0	0	0	0	0	0	0
	1	0	0	0	0	0	0
	2	0	0	6	0	0	0
	3	0	0	6	0	0	0
Segment 2	0						
	1						
	2						
	3						
Segment 3	0						
	1						
	2						
	3						
Segment 4	0						
	1						
	2						
	3						
Segment 5	0						
	1						
	2						
	3						

SAM RESULTS

	Slope as percent of min slope 1993	1994	1995	Width as percent of width at min slope 1993	1994	1995
Segment 1	62	38	46	154	161	153
Segment 2						
Segment 3						
Segment 4						
Segment 5						

Table 5
Abiaca Creek (Site #21) Summary Results

BANK MATERIAL PROPERTIES		BASIN PROPERTIES		SEDIMENT PROPERTIES	
Unit weight:	121 (lbs/ft^3)	2 year flow:	1150 (cfs)	D50:	0.35 (mm)
Cohesion:	331 (lbs/ft^2)			sigma:	1.39

1995 SEGMENT PROPERTIES

	Basin Area (mi^2)	Slope (ft/ft)	Width (ft)	Depth (ft)	Conc (mg/l)	CEM	Segment Stable	Grade Control	Bank Stab.
Segment 1	94.4	0.00032	87	5.5	115	5	y	n	n
Segment 2									
Segment 3									
Segment 4									
Segment 5									

BURBANK RESULTS

	Bed Degradation (feet)	Friction angle: 0 1993	1994	1995	Friction angle: 14.7 1993	1994	1995
Segment 1	0	0	0	0	0	0	0
	1	0	0	0	0	0	0
	2	0	0	0	0	0	0
	3	0	0	0	0	0	0
Segment 2	0						
	1						
	2						
	3						
Segment 3	0						
	1						
	2						
	3						
Segment 4	0						
	1						
	2						
	3						
Segment 5	0						
	1						
	2						
	3						

SAM RESULTS

	Slope as percent of min slope 1993	1994	1995	Width as percent of width at min slope 1993	1994	1995
Segment 1	71	75	41	66	74	57
Segment 2						
Segment 3						
Segment 4						
Segment 5						

Table 6
Burney Branch (Site #12) Summary Results

BANK MATERIAL PROPERTIES		BASIN PROPERTIES		SEDIMENT PROPERTIES	
Unit weight:	120 (lbs/ft^3)	2 year flow:	2662 (cfs)	D50:	0.36 (mm)
Cohesion:	274 (lbs/ft^2)			sigma:	1.65

1995 SEGMENT PROPERTIES

	Basin Area (mi^2)	Slope (ft/ft)	Width (ft)	Depth (ft)	Conc (mg/l)	CEM	Segment Stable	Grade Control	Bank Stab.
Segment 1	9.8	0.00114	96	5.9	1304	0	y	y	y
Segment 2	6.2	0.00114	84	6.4	1434	5	y	n	n
Segment 3									
Segment 4									
Segment 5									

BURBANK RESULTS

	Bed Degradation (feet)	Friction angle: 0 1993	1994	1995	Friction angle: 18.5 1993	1994	1995
Segment 1	0	15	10	5	0	0	0
	1	25	22	20	0	0	0
	2	25	25	20	0	0	0
	3	30	35	40	0	0	0
Segment 2	0	0	0	0	0	0	0
	1	0	0	0	0	0	0
	2	0	0	0	0	0	0
	3	0	3	0	0	0	0
Segment 3	0						
	1						
	2						
	3						
Segment 4	0						
	1						
	2						
	3						
Segment 5	0						
	1						
	2						
	3						

SAM RESULTS

	Slope as percent of min slope 1993	1994	1995	Width as percent of width at min slope 1993	1994	1995
Segment 1	87	91	117	110	107	94
Segment 2	94	101	123	97	95	90
Segment 3						
Segment 4						
Segment 5						

Table 7
Coila Creek (Site #5) Summary Results

BANK MATERIAL PROPERTIES			BASIN PROPERTIES			SEDIMENT PROPERTIES		
Unit weight:	121	(lbs/ft^3)	2 year flow:	730	(cfs)	D50:	10.00	(mm)
Cohesion:	331	(lbs/ft^2)				sigma:	9.31	

1995 SEGMENT PROPERTIES

	Basin Area (mi^2)	Slope (ft/ft)	Width (ft)	Depth (ft)	Conc (mg/l)	CEM	Segment Stable	Grade Control	Bank Stab.
Segment 1	39.2	0.00159	80	2.8	9	5	y	n	n
Segment 2									
Segment 3									
Segment 4									
Segment 5									

BURBANK RESULTS

	Bed Degradation (feet)	Friction angle: 0 1993	1994	1995	Friction angle: 14.7 1993	1994	1995
Segment 1	0	0	0	0	0	0	0
	1	0	7	0	0	0	0
	2	0	14	0	0	0	0
	3	0	7	0	0	7	0
Segment 2	0						
	1						
	2						
	3						
Segment 3	0						
	1						
	2						
	3						
Segment 4	0						
	1						
	2						
	3						
Segment 5	0						
	1						
	2						
	3						

SAM RESULTS

	Slope as percent of min slope 1993	1994	1995	Width as percent of width at min slope 1993	1994	1995
Segment 1	13	22	17	133	186	159
Segment 2						
Segment 3						
Segment 4						
Segment 5						

Table 8
Fannegusha Creek (Site #2) Summary Results

BANK MATERIAL PROPERTIES		BASIN PROPERTIES		SEDIMENT PROPERTIES	
Unit weight:	122 (lbs/ft^3)	2 year flow:	3325 (cfs)	D50:	0.31 (mm)
Cohesion:	413 (lbs/ft^2)			sigma:	1.66

1995 SEGMENT PROPERTIES

	Basin Area (mi^2)	Slope (ft/ft)	Width (ft)	Depth (ft)	Conc (mg/l)	CEM	Segment Stable	Grade Control	Bank Stab.
Segment 1	17.7	0.00096	82	7.8	1685	4	n	y	n
Segment 2									
Segment 3									
Segment 4									
Segment 5									

BURBANK RESULTS

	Bed Degradation (feet)	Friction angle: 0 1993	1994	1995	Friction angle: 13.3 1993	1994	1995
Segment 1	0	0	0	0	0	0	0
	1	0	0	6	0	0	0
	2	0	0	6	0	0	0
	3	0	0	6	0	0	0
Segment 2	0						
	1						
	2						
	3						
Segment 3	0						
	1						
	2						
	3						
Segment 4	0						
	1						
	2						
	3						
Segment 5	0						
	1						
	2						
	3						

SAM RESULTS

	Slope as percent of min slope 1993	1994	1995	Width as percent of width at min slope 1993	1994	1995
Segment 1	184	116	125	110	88	89
Segment 2						
Segment 3						
Segment 4						
Segment 5						

Table 9
Harland Creek (Site #1) Summary Results

BANK MATERIAL PROPERTIES		BASIN PROPERTIES		SEDIMENT PROPERTIES	
Unit weight:	122 (lbs/ft^3)	2 year flow:	1970 (cfs)	D50:	0.50 (mm)
Cohesion:	413 (lbs/ft^2)			sigma:	8.45

1995 SEGMENT PROPERTIES

	Basin Area (mi^2)	Slope (ft/ft)	Width (ft)	Depth (ft)	Conc (mg/l)	CEM	Segment Stable	Grade Control	Bank Stab.
Segment 1	26.9	0.00086	81	6.0	637	0	n	n	y
Segment 2									
Segment 3									
Segment 4									
Segment 5									

BURBANK RESULTS

	Bed Degradation (feet)	Friction angle: 0 1993	1994	1995	Friction angle: 13.3 1993	1994	1995
Segment 1	0	6	2	0	0	2	0
	1	6	2	0	0	2	0
	2	6	2	0	0	2	0
	3	6	9	6	0	2	0
Segment 2	0						
	1						
	2						
	3						
Segment 3	0						
	1						
	2						
	3						
Segment 4	0						
	1						
	2						
	3						
Segment 5	0						
	1						
	2						
	3						

SAM RESULTS

	Slope as percent of min slope 1993	1994	1995	Width as percent of width at min slope 1993	1994	1995
Segment 1	55	62	56	132	134	114
Segment 2						
Segment 3						
Segment 4						
Segment 5						

Table 10
Harland Creek (Site 23) Summary Results

BANK MATERIAL PROPERTIES		BASIN PROPERTIES		SEDIMENT PROPERTIES	
Unit weight:	122 (lbs/ft^3)	2 year flow:	750 (cfs)	D50:	0.50 (mm)
Cohesion:	413 (lbs/ft^2)			sigma:	8.45

1995 SEGMENT PROPERTIES

	Basin Area (mi^2)	Slope (ft/ft)	Width (ft)	Depth (ft)	Conc (mg/l)	CEM	Segment Stable	Grade Control	Bank Stab.
Segment 1	40.3	0.00084	73	3.6	340	0	n	n	y
Segment 2									
Segment 3									
Segment 4									
Segment 5									

BURBANK RESULTS

	Bed Degradation (feet)	Friction angle: 0 1993	1994	1995	Friction angle: 13.3 1993	1994	1995
Segment 1	0	2	5	2	2	5	2
	1	2	5	2	2	5	2
	2	5	7	2	2	5	2
	3	7	10	5	2	5	2
Segment 2	0						
	1						
	2						
	3						
Segment 3	0						
	1						
	2						
	3						
Segment 4	0						
	1						
	2						
	3						
Segment 5	0						
	1						
	2						
	3						

SAM RESULTS

	Slope as percent of min slope 1993	1994	1995	Width as percent of width at min slope 1993	1994	1995
Segment 1	40	55	39	128	138	133
Segment 2						
Segment 3						
Segment 4						
Segment 5						

Table 11
Hickahala Creek (Site #11) Summary Results

BANK MATERIAL PROPERTIES		BASIN PROPERTIES		SEDIMENT PROPERTIES	
Unit weight:	125 (lbs/ft^3)	2 year flow:	1290 (cfs)	D50:	0.50 (mm)
Cohesion:	450 (lbs/ft^2)			sigma:	1.83

1995 SEGMENT PROPERTIES

	Basin Area (mi^2)	Slope (ft/ft)	Width (ft)	Depth (ft)	Conc (mg/l)	CEM	Segment Stable	Grade Control	Bank Stab.
Segment 1	10.4	0.00153	49	5.3	1525	1	n	n	n
Segment 2	5.0	0.00173	40	5.7	2388	3	n	y	n
Segment 3									
Segment 4									
Segment 5									

BURBANK RESULTS

	Bed Degradation (feet)	Friction angle: 0 1993	1994	1995	Friction angle: 8 1993	1994	1995
Segment 1	0	0	17	0	0	0	0
	1	0	17	0	0	17	0
	2	0	33	0	0	17	0
	3	17	33	0	0	17	0
Segment 2	0	0	0	0	0	0	0
	1	0	0	0	0	0	0
	2	0	8	0	0	0	0
	3	0	8	0	0	0	0
Segment 3	0						
	1						
	2						
	3						
Segment 4	0						
	1						
	2						
	3						
Segment 5	0						
	1						
	2						
	3						

SAM RESULTS

	Slope as percent of min slope 1993	1994	1995	Width as percent of width at min slope 1993	1994	1995
Segment 1	91	121	128	109	105	98
Segment 2	123	136	159	104	98	97
Segment 3						
Segment 4						
Segment 5						

Table 12
Hotopha Creek (Site #13) Summary Results

BANK MATERIAL PROPERTIES		BASIN PROPERTIES		SEDIMENT PROPERTIES	
Unit weight:	120 (lbs/ft^3)	2 year flow:	3386 (cfs)	D50:	0.30 (mm)
Cohesion:	274 (lbs/ft^2)			sigma:	4.08

1995 SEGMENT PROPERTIES

	Basin Area (mi^2)	Slope (ft/ft)	Width (ft)	Depth (ft)	Conc (mg/l)	CEM	Segment Stable	Grade Control	Bank Stab.
Segment 1	19.9	0.00184	71	7.1	4758	0	n	y	n
Segment 2	16.2	0.00083	71	9.1	1340	0	n	y	n
Segment 3	10.1	0.00107	75	8.0	2157	0	n	y	n
Segment 4									
Segment 5									

BURBANK RESULTS

	Bed Degradation (feet)	Friction angle: 0 1993	1994	1995	Friction angle: 18.5 1993	1994	1995
Segment 1	0			100			0
	1	1)	2)	100	1)	2)	0
	2			100			0
	3			100			0
Segment 2	0	75	83	80	8	12	5
	1	75	83	82	12	12	9
	2	75	83	82	12	17	9
	3	75	83	82	25	25	12
Segment 3	0	21	21	20	0	0	0
	1	24	24	20	0	0	0
	2	24	24	23	0	3	3
	3	24	24	27	0	3	3
Segment 4	0						
	1						
	2						
	3						
Segment 5	0						
	1						
	2						
	3						

1) Part of segment 2 in 1993
2) No access to site due to construction during 1994.

SAM RESULTS

	Slope as percent of min slope 1993	1994	1995	Width as percent of width at min slope 1993	1994	1995
Segment 1			208			76
Segment 2	242	118	102	88	125	101
Segment 3	43	65	112	100	193	215
Segment 4						
Segment 5						

Table 13
James Wolf Creek (Site #19) Summary Results

BANK MATERIAL PROPERTIES		BASIN PROPERTIES		SEDIMENT PROPERTIES	
Unit weight:	124 (lbs/ft^3)	2 year flow:	2189 (cfs)	D50:	0.35 (mm)
Cohesion:	226 (lbs/ft^2)			sigma:	1.55

1995 SEGMENT PROPERTIES

	Basin Area (mi^2)	Slope (ft/ft)	Width (ft)	Depth (ft)	Conc (mg/l)	CEM	Segment Stable	Grade Control	Bank Stab.
Segment 1	10.1	0.00175	70	5.6	3027	3	n	y	y
Segment 2	9.6	0.00164	73	5.6	2673	3	n	y	n
Segment 3									
Segment 4									
Segment 5									

BURBANK RESULTS

	Bed Degradation (feet)	Friction angle: 0 1993	1994	1995	Friction angle: 9 1993	1994	1995
Segment 1	0	100	100	100	100	100	100
	1	100	100	100	100	100	100
	2	100	100	100	100	100	100
	3	100	100	100	100	100	100
Segment 2	0	56	62	62	44	50	50
	1	56	62	62	44	50	50
	2	56	62	62	44	50	50
	3	56	62	62	44	50	50
Segment 3	0						
	1						
	2						
	3						
Segment 4	0						
	1						
	2						
	3						
Segment 5	0						
	1						
	2						
	3						

SAM RESULTS

	Slope as percent of min slope 1993	1994	1995	Width as percent of width at min slope 1993	1994	1995
Segment 1	159	196	222	125	121	124
Segment 2	171	189	204	134	135	130
Segment 3						
Segment 4						
Segment 5						

Table 14
Lee Creek (Site #10) Summary Results

BANK MATERIAL PROPERTIES
Unit weight: 118 (lbs/ft^3)
Cohesion: 356 (lbs/ft^2)

BASIN PROPERTIES
2 year flow: 1377 (cfs)

SEDIMENT PROPERTIES
D50: 0.40 (mm)
sigma: 1.61

1995 SEGMENT PROPERTIES

	Basin Area (mi^2)	Slope (ft/ft)	Width (ft)	Depth (ft)	Conc (mg/l)	CEM	Segment Stable	Grade Control	Bank Stab.
Segment 1	6.1	0.00156	43	4.5	1620	0	n	n	n
Segment 2									
Segment 3									
Segment 4									
Segment 5									

BURBANK RESULTS

	Bed Degradation (feet)	Friction angle: 0 1993	1994	1995	Friction angle: 17.3 1993	1994	1995
Segment 1	0	0	0	0	0	0	0
	1	0	0	0	0	0	0
	2	0	0	0	0	0	0
	3	6	6	0	0	0	0
Segment 2	0						
	1						
	2						
	3						
Segment 3	0						
	1						
	2						
	3						
Segment 4	0						
	1						
	2						
	3						
Segment 5	0						
	1						
	2						
	3						

SAM RESULTS

	Slope as percent of min slope 1993	1994	1995	Width as percent of width at min slope 1993	1994	1995
Segment 1	132	136	133	97	102	80
Segment 2						
Segment 3						
Segment 4						
Segment 5						

Table 15
Lick Creek (Site #8) Summary Results

BANK MATERIAL PROPERTIES
Unit weight: 118 (lbs/ft^3)
Cohesion: 356 (lbs/ft^2)

BASIN PROPERTIES
2 year flow: 1580 (cfs)

SEDIMENT PROPERTIES
D50: 0.61 (mm)
sigma: 3.42

1995 SEGMENT PROPERTIES

	Basin Area (mi^2)	Slope (ft/ft)	Width (ft)	Depth (ft)	Conc (mg/l)	CEM	Segment Stable	Grade Control	Bank Stab.
Segment 1	6.7	0.00301	61	4.2	3862	3	n	n	n
Segment 2	6.7	0.00241	41	5.8	3649	2	n	y	n
Segment 3									
Segment 4									
Segment 5									

BURBANK RESULTS

	Bed Degradation (feet)	Friction angle: 0 1993	1994	1995	Friction angle: 17.3 1993	1994	1995
Segment 1	0	0	0	0	0	0	0
	1	17	0	0	0	0	0
	2	17	0	0	0	0	0
	3	33	12	50	0	0	0
Segment 2	0	0	0	0	0	0	0
	1	6	0	6	0	0	0
	2	6	0	12	0	0	0
	3	6	12	12	0	0	0
Segment 3	0						
	1						
	2						
	3						
Segment 4	0						
	1						
	2						
	3						
Segment 5	0						
	1						
	2						
	3						

SAM RESULTS

	Slope as percent of min slope 1993	1994	1995	Width as percent of width at min slope 1993	1994	1995
Segment 1	215	205	231	125	124	142
Segment 2	118	194	186	91	100	97
Segment 3						
Segment 4						
Segment 5						

Table 16
Long Creek (Site #20) Summary Results

BANK MATERIAL PROPERTIES		BASIN PROPERTIES		SEDIMENT PROPERTIES	
Unit weight:	130 (lbs/ft^3)	2 year flow:	960 (cfs)	D50:	0.38 (mm)
Cohesion:	270 (lbs/ft^2)			sigma:	2.12

1995 SEGMENT PROPERTIES

	Basin Area (mi^2)	Slope (ft/ft)	Width (ft)	Depth (ft)	Conc (mg/l)	CEM	Segment Stable	Grade Control	Bank Stab.
Segment 1	10.2	0.00193	48	4.1	2485	3	n	y	n
Segment 2	10.2	0.00135	69	3.7	1020	5	y	y	n
Segment 3	10.1	0.00198	45	4.3	2703	2	n	y	y
Segment 4	7.8	0.00137	58	4.1	1172	1	y	y	y
Segment 5									

BURBANK RESULTS

	Bed Degradation (feet)	Friction angle: 0 1993	1994	1995	Friction angle: 16 1993	1994	1995
Segment 1	0	70	38	33	0	0	0
	1	70	100	100	0	12	0
	2	90	100	100	0	12	0
	3	100	100	100	0	12	0
Segment 2	0	8	11	22	0	0	0
	1	8	17	22	0	0	0
	2	8	17	22	4	0	0
	3	27	28	33	4	6	0
Segment 3	0	8	4	11	0	0	0
	1	10	11	21	0	4	0
	2	18	18	21	2	4	4
	3	25	21	29	2	4	4
Segment 4	0	0	0	0	0	0	0
	1	2	0	0	0	0	0
	2	2	3	3	0	0	0
	3	2	3	6	0	0	0
Segment 5	0						
	1						
	2						
	3						

SAM RESULTS

	Slope as percent of min slope 1993	1994	1995	Width as percent of width at min slope 1993	1994	1995
Segment 1	134	74	172	118	112	96
Segment 2	86	132	101	98	103	101
Segment 3	196	383	186	105	90	104
Segment 4	133	171	112	82	89	104
Segment 5						

Table 17
Nolehoe Creek (Site #7) Summary Results

BANK MATERIAL PROPERTIES
Unit weight: 118 (lbs/ft^3)
Cohesion: 356 (lbs/ft^2)

BASIN PROPERTIES
2 year flow: 978 (cfs)

SEDIMENT PROPERTIES
D50: 10.00 (mm)
sigma: 3.54

1995 SEGMENT PROPERTIES

	Basin Area (mi^2)	Slope (ft/ft)	Width (ft)	Depth (ft)	Conc (mg/l)	CEM	Segment Stable	Grade Control	Bank Stab.
Segment 1	3.3	0.00236	38	4.6	3239	4	n	n	n
Segment 2	2.7	0.00645	26	4.2	16499	2	n	n	n
Segment 3									
Segment 4									
Segment 5									

BURBANK RESULTS

	Bed Degradation (feet)	Friction angle: 0 1993	1994	1995	Friction angle: 17.3 1993	1994	1995
Segment 1	0	10	20	0	10	0	0
	1	50	40	0	10	10	0
	2	60	40	20	10	10	0
	3	90	80	60	10	10	0
Segment 2	0	0	6	0	0	0	0
	1	6	6	0	0	0	0
	2	6	12	0	0	0	0
	3	12	19	0	0	0	0
Segment 3	0						
	1						
	2						
	3						
Segment 4	0						
	1						
	2						
	3						
Segment 5	0						
	1						
	2						
	3						

SAM RESULTS

	Slope as percent of min slope 1993	1994	1995	Width as percent of width at min slope 1993	1994	1995
Segment 1	174	177	163	156	145	118
Segment 2	399	402	419	89	87	83
Segment 3						
Segment 4						

Table 18
Otoucalofa Creek (Site #14) Summary Results

BANK MATERIAL PROPERTIES		BASIN PROPERTIES		SEDIMENT PROPERTIES	
Unit weight:	122 (lbs/ft^3)	2 year flow:	2600 (cfs)	D50:	0.40 (mm)
Cohesion:	413 (lbs/ft^2)			sigma:	2.31

1995 SEGMENT PROPERTIES

	Basin Area (mi^2)	Slope (ft/ft)	Width (ft)	Depth (ft)	Conc (mg/l)	CEM	Segment Stable	Grade Control	Bank Stab.
Segment 1	47.1	0.00113	69	7.1	1503	3	n	n	y
Segment 2	46.4	0.00097	71	7.3	1185	3	n	n	y
Segment 3									
Segment 4									
Segment 5									

BURBANK RESULTS

	Bed Degradation (feet)	Friction angle: 0 1993	1994	1995	Friction angle: 13.3 1993	1994	1995
Segment 1	0	0	0	0	0	0	0
	1	0	0	0	0	0	0
	2	0	0	0	0	0	0
	3	0	0	0	0	0	0
Segment 2	0	0	0	0	0	0	0
	1	0	0	0	0	0	0
	2	0	0	0	0	0	0
	3	0	0	0	0	0	0
Segment 3	0						
	1						
	2						
	3						
Segment 4	0						
	1						
	2						
	3						
Segment 5	0						
	1						
	2						
	3						

SAM RESULTS

	Slope as percent of min slope 1993	1994	1995	Width as percent of width at min slope 1993	1994	1995
Segment 1	137	127	136	75	75	64
Segment 2	158	111	119	66	78	75
Segment 3						
Segment 4						
Segment 5						

Table 19
Perry Creek (Site #16) Summary Results

BANK MATERIAL PROPERTIES		BASIN PROPERTIES		SEDIMENT PROPERTIES	
Unit weight:	124 (lbs/ft^3)	2 year flow:	1790 (cfs)	D50:	0.32 (mm)
Cohesion:	177 (lbs/ft^2)			sigma:	2.54

1995 SEGMENT PROPERTIES

	Basin Area (mi^2)	Slope (ft/ft)	Width (ft)	Depth (ft)	Conc (mg/l)	CEM	Segment Stable	Grade Control	Bank Stab.
Segment 1	7.5	0.00126	94	4.6	1277	0	n	n	n
Segment 2	7.4	0.00071	77	6.1	628	0	n	y	n
Segment 3	7.3	0.00168	49	6.2	3388	4	n	y	n
Segment 4	4.5	0.00294	49	5.2	7398	2	n	y	n
Segment 5									

BURBANK RESULTS

	Bed Degradation (feet)	Friction angle: 0 1993	1994	1995	Friction angle: 22 1993	1994	1995
	0	100	100	100	0	0	0
Segment 1	1	100	100	100	25	25	0
	2	100	100	100	25	25	0
	3	100	100	100	25	25	0
	0	65	65	70	0	10	5
Segment 2	1	75	75	70	10	10	5
	2	75	75	75	10	20	5
	3	75	75	75	5	15	10
	0	39	34	39	3	0	0
Segment 3	1	39	34	39	6	0	0
	2	39	37	39	6	3	3
	3	39	39	39	9	3	3
	0	10	10	13	2	2	0
Segment 4	1	10	12	13	2	2	0
	2	10	15	13	2	2	0
	3	10	15	13	2	2	0
	0						
Segment 5	1						
	2						
	3						

SAM RESULTS

	Slope as percent of min slope 1993	1994	1995	Width as percent of width at min slope 1993	1994	1995
Segment 1	142	128	118	96	113	111
Segment 2	117	105	74	117	100	114
Segment 3	212	247	184	101	95	81
Segment 4	485	341	284	51	69	64
Segment 5						

Table 20
Redbanks Creek (Site #9) Summary Results

BANK MATERIAL PROPERTIES

Unit weight: 124 (lbs/ft^3)
Cohesion: ‘177 (lbs/ft^2)

BASIN PROPERTIES

2 year flow: 3951 (cfs)

SEDIMENT PROPERTIES

D50: 0.50 (mm)
sigma: 1.81

1995 SEGMENT PROPERTIES

	Basin Area (mi^2)	Slope (ft/ft)	Width (ft)	Depth (ft)	Conc (mg/l)	CEM	Segment Stable	Grade Control	Bank Stab.
Segment 1	25.3	0.00129	113	6.6	1425	0	n	n	y
Segment 2	25.2	0.00180	97	6.5	2884	0	n	y	y
Segment 3	25.2	0.00211	96	6.2	3660	0	n	y	y
Segment 4	25.2	0.00169	108	6.2	2462	0	n	y	y
Segment 5	25.1	0.00188	98	6.4	3044				

BURBANK RESULTS

	Bed Degradation (feet)	Friction angle: 0			Friction angle: 22		
		1993	1994	1995	1993	1994	1995
	0	100	100	100	0	0	0
Segment 1	1	100	100	100	0	0	0
	2	100	100	100	0	0	6
	3	100	100	100	6	0	11
	0	31	31	31	0	0	0
Segment 2	1	31	31	31	0	0	0
	2	31	31	31	0	0	0
	3	31	31	31	4	0	0
	0	24	24	24	3	3	0
Segment 3	1	24	24	24	3	3	0
	2	24	24	24	6	3	0
	3	24	24	24	6	3	0
	0	29	29	29	0	2	0
Segment 4	1	29	29	29	0	2	0
	2	29	29	29	6	0	4
	3	29	29	29	8	2	2
	0	8	8	8	2	2	2
Segment 5	1	8	8	8	4	2	2
	2	8	8	8	6	2	2
	3	8	8	8	6	2	2

SAM RESULTS

	Slope as percent of min slope			Width as percent of width at min slope		
	1993	1994	1995	1993	1994	1995
Segment 1	141	150	130	129	111	112
Segment 2	246	251	192	126	112	110
Segment 3	220	249	233	121	121	126
Segment 4	209	103	181	140	113	123
Segment 5	272	130	224	156	154	156

Table 21
Sarter Creek (Site 15) Summary Results

BANK MATERIAL PROPERTIES
Unit weight: 121 (lbs/ft^3)
Cohesion: 331 (lbs/ft^2)

BASIN PROPERTIES
2 year flow: 1391 (cfs)

SEDIMENT PROPERTIES
D50: 0.37 (mm)
sigma: 1.87

1995 SEGMENT PROPERTIES

	Basin Area (mi^2)	Slope (ft/ft)	Width (ft)	Depth (ft)	Conc (mg/l)	CEM	Segment Stable	Grade Control	Bank Stab.
Segment 1	6.4	0.00152	41	5.1	2076	3	n	n	n
Segment 2									
Segment 3									
Segment 4									
Segment 5									

BURBANK RESULTS

	Bed Degradation (feet)	Friction angle: 0 1993	1994	1995	Friction angle: 14.7 1993	1994	1995
Segment 1	0	0	0	0	0	0	0
	1	0	0	0	0	0	0
	2	0	0	0	0	0	0
	3	12	12	0	0	0	0
Segment 2	0						
	1						
	2						
	3						
Segment 3	0						
	1						
	2						
	3						
Segment 4	0						
	1						
	2						
	3						
Segment 5	0						
	1						
	2						
	3						

SAM RESULTS

	Slope as percent of min slope 1993	1994	1995	Width as percent of width at min slope 1993	1994	1995
Segment 1	146	143	129	90	89	70
Segment 2						
Segment 3						
Segment 4						
Segment 5						

Table 22
Sykes Creek (Site #17) Summary Results

BANK MATERIAL PROPERTIES		BASIN PROPERTIES		SEDIMENT PROPERTIES	
Unit weight:	121 (lbs/ft^3)	2 year flow:	2545 (cfs)	D50:	0.34 (mm)
Cohesion:	331 (lbs/ft^2)			sigma:	1.58

1995 SEGMENT PROPERTIES

	Basin Area (mi^2)	Slope (ft/ft)	Width (ft)	Depth (ft)	Conc (mg/l)	CEM	Segment Stable	Grade Control	Bank Stab.
Segment 1	11.8	0.00192	72	5.9	3932	4	n	n	n
Segment 2									
Segment 3									
Segment 4									
Segment 5									

BURBANK RESULTS

	Bed Degradation (feet)	Friction angle: 0 1993	1994	1995	Friction angle: 14.7 1993	1994	1995
Segment 1	0	12	12	12	0	0	0
	1	12	25	19	0	0	0
	2	19	31	31	6	0	0
	3	38	38	44	12	0	0
Segment 2	0						
	1						
	2						
	3						
Segment 3	0						
	1						
	2						
	3						
Segment 4	0						
	1						
	2						
	3						
Segment 5	0						
	1						
	2						
	3						

SAM RESULTS

	Slope as percent of min slope 1993	1994	1995	Width as percent of width at min slope 1993	1994	1995
Segment 1	201	184	211	85	94	71
Segment 2						
Segment 3						
Segment 4						
Segment 5						

Table 23
East Worsham Creek (Site #18a) Summary Results

BANK MATERIAL PROPERTIES
Unit weight: 125 (lbs/ft^3)
Cohesion: 276 (lbs/ft^2)

BASIN PROPERTIES
2 year flow: 1935 (cfs)

SEDIMENT PROPERTIES
D50: 0.25 (mm)
sigma: 1.77

1995 SEGMENT PROPERTIES

	Basin Area (mi^2)	Slope (ft/ft)	Width (ft)	Depth (ft)	Conc (mg/l)	CEM	Segment Stable	Grade Control	Bank Stab.
Segment 1	9.3	0.00180	46	6.2	4819	2	n	n	n
Segment 2	9.1	0.00171	51	6.3	4227	3	n	y	n
Segment 3	9.0	0.00181	51	6.2	4515	1	n	y	n
Segment 4									
Segment 5									

BURBANK RESULTS

	Bed Degradation (feet)	Friction angle: 0 1993	1994	1995	Friction angle: 14 1993	1994	1995
Segment 1	0	100	100	100	50	25	50
	1	100	100	100	67	58	52
	2	100	100	100	67	68	60
	3	100	100	100	74	68	67
Segment 2	0	22	25	25	0	0	0
	1	22	25	25	6	6	6
	2	22	25	25	6	6	6
	3	22	25	25	6	19	6
Segment 3	0	4	9	5	0	0	0
	1	7	9	5	0	0	0
	2	11	14	5	0	0	0
	3	14	23	9	0	0	0
Segment 4	0						
	1						
	2						
	3						
Segment 5	0						
	1						
	2						
	3						

SAM RESULTS

	Slope as percent of min slope 1993	1994	1995	Width as percent of width at min slope 1993	1994	1995
Segment 1	277	268	251	90	88	75
Segment 2	292	240	250	93	93	96
Segment 3	211	248	252	86	99	83
Segment 4						
Segment 5						

Table 24
Middle Worsham Creek (Site #18b) Summary Results

BANK MATERIAL PROPERTIES		BASIN PROPERTIES		SEDIMENT PROPERTIES	
Unit weight:	118 (lbs/ft^3)	2 year flow:	1153 (cfs)	D50:	0.30 (mm)
Cohesion:	233 (lbs/ft^2)			sigma:	1.87

1995 SEGMENT PROPERTIES

	Basin Area (mi^2)	Slope (ft/ft)	Width (ft)	Depth (ft)	Conc (mg/l)	CEM	Segment Stable	Grade Control	Bank Stab.
Segment 1	5.2	0.00173	43	5.1	3158	2	n	n	n
Segment 2	4.7	0.00175	42	5.2	3237	3	n	y	n
Segment 3	4.2	0.00106	51	5.4	1220	4	n	y	n
Segment 4	4.1	0.00311	36	4.8	8027	3	n	y	n
Segment 5									

BURBANK RESULTS

	Bed Degradation (feet)	Friction angle: 0 1993	1994	1995	Friction angle: 11 1993	1994	1995
Segment 1	0	100	100	67	17	0	25
	1	100	100	67	18	8	42
	2	100	100	83	45	42	42
	3	100	100	100	43	42	33
Segment 2	0	42	38	38	0	0	0
	1	42	42	38	0	0	0
	2	42	46	42	0	0	4
	3	42	50	46	4	0	4
Segment 3	0	9	12	9	0	0	0
	1	15	12	12	0	3	0
	2	24	12	16	0	3	0
	3	26	19	19	0	3	0
Segment 4	0	5	8	3	0	3	0
	1	15	8	3	0	3	0
	2	15	8	6	0	3	0
	3	15	11	8	0	3	0
Segment 5	0						
	1						
	2						
	3						

SAM RESULTS

	Slope as percent of min slope 1993	1994	1995	Width as percent of width at min slope 1993	1994	1995
Segment 1	215	174	191	92	91	89
Segment 2	303	230	197	93	85	88
Segment 3	128	149	122	110	122	105
Segment 4	452	435	361	85	87	75
Segment 5						

Table 25
West Worsham Creek (Site #18c) Summary Results

BANK MATERIAL PROPERTIES
Unit weight: 119 (lbs/ft^3)
Cohesion: 343 (lbs/ft^2)

BASIN PROPERTIES
2 year flow: 1096 (cfs)

SEDIMENT PROPERTIES
D50: 0.31 (mm)
sigma: 1.83

1995 SEGMENT PROPERTIES

	Basin Area (mi^2)	Slope (ft/ft)	Width (ft)	Depth (ft)	Conc (mg/l)	CEM	Segment Stable	Grade Control	Bank Stab.
Segment 1	4.1	0.00156	34	5.9	2908	2	n	n	n
Segment 2	3.6	0.00211	40	4.9	4018	3	n	y	n
Segment 3	2.9	0.00155	50	4.7	2208	3	n	y	n
Segment 4	2.5	0.00492	30	4.5	15694	2	n	y	n
Segment 5									

BURBANK RESULTS

	Bed Degradation (feet)	Friction angle: 0 1993	1994	1995	Friction angle: 18 1993	1994	1995
Segment 1	0	40	40	60	0	0	0
	1	50	50	70	0	0	0
	2	70	60	80	0	0	0
	3	80	70	100	0	0	0
Segment 2	0	5	5	10	0	0	0
	1	9	10	20	0	0	0
	2	18	20	25	0	0	0
	3	18	30	30	0	0	0
Segment 3	0	6	7	7	0	0	0
	1	6	10	7	0	0	0
	2	15	13	13	0	0	0
	3	18	17	20	0	0	0
Segment 4	0	0	0	0	0	0	0
	1	0	0	0	0	0	0
	2	0	0	0	0	0	0
	3	0	0	0	0	0	0
Segment 5	0						
	1						
	2						
	3						

SAM RESULTS

	Slope as percent of min slope 1993	1994	1995	Width as percent of width at min slope 1993	1994	1995
Segment 1	187	190	172	73	72	73
Segment 2	235	301	232	83	83	86
Segment 3	247	169	168	88	105	109
Segment 4	556	299	528	64	79	66
Segment 5						

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14. ABSTRACT
The purpose of the Demonstration Erosion Control (DEC) Project is to evaluate and document watershed response to the implemented DEC Project. Documentation of watershed responses to DEC Project features will allow the participating agencies a unique opportunity to determine the effectiveness of existing design guidance for erosion and flood control in small watersheds. The monitoring program includes 11 technical areas: stream gauging, data collection, hydraulic performance of structures, channel response, hydrology, upland watersheds, reservoir sedimentation, environmental aspects, bank stability, design tools, and technology transfer.

This report includes detailed discussion of the channel response technical area that was investigated by the U.S. Army Research and Development Center (ERDC) during Fiscal Year 1995.

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